



وزارة التعليم العالي والبحث العلمي
الجامعة التقنية الشمالية
كلية البوالتكنك الموصل



الحقبة التعليمية

القسم العلمي: تقنيات هندسة الاوتوترونيكس

اسم المقرر: Power transmission systems

المرحلة / المستوى: الثاني

الفصل الدراسي: الاول

السنة الدراسية: ٢٠٢٦/٢٠٢٧





اسم المقرر:					Power transmission systems				
القسم:					تقنيات هندسة الاوتوترونيكس				
كلية:					البوليتكنك الموصل				
المرحلة / المستوى					الثاني				
الفصل الدراسي:					الاول				
عدد الساعات الاسبوعية:					نظري ٢ عملي ٤				
عدد الوحدات الدراسية:					٦				
الرمز:					ATD201				
نوع المادة					نظري عملي كلهما ✓				
هل يتوفر نظير للمقرر في الاقسام الاخرى					لا				
اسم المقرر النظير					-				
القسم					-				
رمز المقرر النظير					-				
معلومات تدريسي المادة									
اسم مدرس (مدرسي) المقرر:					لبنى علي حسين				
اللقب العلمي:					مدرس مساعد				
سنة الحصول على اللقب					٢٠٢٢				
الشهادة:					ماجستير				
سنة الحصول على الشهادة					٢٠٢٢				
عدد سنوات الخبرة (تدريس)					٤ سنوات				

الوصف العام للمقرر

يهدف هذا المقرر إلى تزويد الطلبة بفهم شامل ومستفيض للمبادئ الأساسية والتقنية التي تحكم عمل منظومات نقل القدرة (Power Transmission Systems) في المركبات والآلات الميكانيكية. يشمل المقرر دراسة تحليلية وتطبيقية للأجزاء المكونة لخط نقل الحركة بدءاً من القابض (Clutch)، وصناديق التروس اليدوية والأوتوماتيكية (Manual & Automatic Transmissions)، وصولاً إلى أعمدة التوصيل (Drive Shafts) والتروس الفرقية (Differentials) والمحاور. كما يركز المقرر على حساب نسب التخفيض، العزوم، والسرعات، مع تسليط الضوء على المنظومات الحديثة والمستمرة التغير (CVT) والأنظمة الهجينة والكهربائية لمواكبة التطور التكنولوجي الجاري.

الأهداف العامة

حدد الأهداف الرئيسية للمقرر:

- تزويد الطلاب بفهم علمي وعملي دقيق لمكونات ووظائف وطرق عمل مختلف منظومات نقل القدرة الميكانيكية والهيدروليكية في المركبات.
- تمكين الطلاب من تطبيق القوانين الهندسية لحساب نسب التروس، العزوم المنقولة، والسرعات الدورانية بكفاءة.
- تنمية مهارات التشخيص والتحليل الهندسي لتحديد الأعطال الشائعة في أجزاء ناقل الحركة ووضع الحلول الهندسية والصيانة المناسبة لها.
- إكساب الطلاب القدرة على المقارنة بين الأنظمة التقليدية والحديثة (مثل منظومات نقل القدرة في المركبات الهجينة والكهربائية) لتهيئتهم لمتطلبات سوق العمل الهندسي.

الأهداف الخاصة

- تمكين الطالب من الانتقال من المفاهيم الفيزيائية والنظرية العامة للتروس والعزوم إلى التطبيق الهندسي والتشخيصي الدقيق لخطوط نقل الحركة في المركبات والآلات.
- حساب وتحليل الكفاءة الميكانيكية، ونسب التخفيض المركبة، وعزم الدوران الناتج من صناديق التروس بمختلف أنواعها.
- تحديد وحساب الإجهادات والأحمال المؤثرة على أعمدة نقل القدرة (Drive Shafts)، المحاور، والتروس المختلفة عند ظروف التشغيل المتغيرة.
- إيجاد وحساب فروق السرعات والعزوم بين العجلات التشغيلية عند المنعطفات باستخدام القوانين الرياضية الحاكمة للمجموعة الفرقية (Differential).

١. الأهداف المعرفية (Cognitive Objectives)

- فهم مبادئ وتصنيفات منظومات نقل الحركة المختلفة، واستيعاب كيفية الانتقال التكنولوجي من الأنظمة التقليدية (اليديوية والأوتوماتيكية) إلى المنظومات الحديثة (CVT) والأنظمة الهجينة والكهربائية.
- تحليل أنظمة نقل القدرة: القدرة على التمييز بين أنواع التروس (العدلة، الحلزونية، والمخروطية) ومجموعات التروس الكوكبية (Planetary Gear Sets)، وفهم طرق تشغيلها وتوزيع العزوم والسرعات بداخلها.

- استيعاب خصائص المكونات الهيدروليكية والإلكترونية: فهم المفاهيم الرياضية والهندسية لعمل محولات العزم الهيدروليكية (Torque Converters) ومجموعات القوابض الرطبة والجافة، كتمهيد لتصميم وبرمجة وحدات التحكم الخاصة بناقل الحركة الذكي.

٢. الأهداف المهارية والتحليلية (Analytical Skills)

- إتقان تحليل خط نقل القدرة: تطوير القدرة على تجريد المنظومة الميكانيكية المعقدة وتمثيل تدفق العزم والسرعة بوضوح من المحرك وحتى العجلات، وهي المهارة الأهم في تشخيص أعطال ناقل الحركة.
- تحليل المجموعات التروسية المركبة: اكتساب القدرة على حساب نسب التخفيض الكلية (Overall Gear Ratios) والسرعات الدورانية للمجموعات التروسية البسيطة والكوكبية (Planetary Gear Sets) لتحديد مدى كفاءتها واستقرارها التشغيلي.
- حل مشكلات الاحتكاك ونقل العزم: تقدير قوى الاحتكاك في القوابض الجافة والرطبة (Clutches) وتأثيرها على كفاءة نقل العزم والقدرة ومنع الانزلاق (Slippage).

٣. الأهداف التطبيقية (Practical Objectives)

- النمذجة الرياضية للمنظومة: تحويل المشاكل الواقعية في ناقل الحركة (مثل انزلاق القابض، أو فقدان القدرة في محول العزم الهيدروليكي) إلى نماذج رياضية وحسابية قابلة للحل باستخدام معادلات الكفاءة الميكانيكية والهيدروليكية.
- استخدام الوحدات القياسية: التمكن من التحويل والتعامل الدقيق مع نظام الوحدات الدولي (SI Unit) مثل حساب القدرة بـ (كيلوواط kW أو الحصان hp) والعزم بـ (نيوتن. متر N.m) لضمان سلامة الحسابات التصميمية والتشخيصية.
- الدقة في الحسابات: تنمية مهارة الوصول إلى نتائج رقمية دقيقة عند حساب خلوصات التروس وتوافقها، حيث أن الخطأ البسيط في أبعاد المسننات أو خلوص القوابض قد يؤدي إلى فشل المنظومة بالكامل وتلفها.

الأهداف السلوكية او نواتج التعلم

- التفكير المنطقي: تعزيز منهجية البحث والحل المتسلسل (الفرضية، الرسم والتخطيط، التعويض، التحقق من العطل) لتشخيص المشاكل الميكانيكية والهيدروليكية بأسلوب علمي سليم.
- العمل الجماعي: من خلال جلسات الحلول المشتركة وورش العمل التطبيقية في مسار بولونيا، يهدف المقرر لتطوير مهارة النقاش التقني وحل مشكلات الصيانة وإعادة بناء المنظومات (Overhauling) ضمن فريق عمل متكامل.

المتطلبات السابقة

- لا يوجد متطلبات سابقة

أساليب التدريس (حدد مجموعة متنوعة من أساليب التدريس لتناسب احتياجات الطلاب ومحتوى المقرر)	
الاسلوب او الطريقة	مبررات الاختيار
١. اسلوب المحاضرات الحديثة	شرح مفاهيم وقوانين نقل القدرة بالتفصيل، وتوضيح كيفية تدفق العزم والسرعة ميكانيكياً وهيدروليكيًا عبر أجزاء ناقل الحركة.
٢. عرض الفيديوهات	استخدام التكنولوجيا التوضيحية (مثل فيديوهات تفكيك الصناديق التروسية والمحاكاة ثلاثية الأبعاد (3D) لتبيين حركة التروس الكوكبية ومحول العزم الهيدروليكي التي يصعب تخيلها نظرياً.
٣. التعلم النشط	إجراء بعض الأنشطة والتجارب المختبرية والورشوية لتصل الفكرة بصورة سريعة، مثل فحص وضبط خلوصات القوابض وتتبع مسارات الزيت في ناقل الحركة الأوتوماتيكي.
٤. طريقة العصف الذهني	تنمية القدرات الذهنية والابداعية لدى الطلاب عبر طرح تساؤلات ميكانيكية مفاجئة، مثل: "ماذا يحدث لعزم وسرعة السيارة عند تلف القابض أو حدوث انزلاق؟"
٥. التعليم القائم	وجود مشكلة أو عطل معين (مثل تأخر التعشيق أو سماع ضوضاء في التروس) فيتم منح الطالب المشكلة ليجتهد عن أسبابها الهندسية ويقترح حلول الصيانة المناسبة، وتعتبر هذه من أفضل الطرق غير المباشرة.
٦. طريقة المجموعات	تشكيل مجموعات من الطلاب لمناقشة ولحل مسائل تتعلق بالمقرر، أو العمل المشترك داخل الورشة لتفكيك وإعادة تجميع (Overhauling) صندوق تروس يدوي أو فرقي.

الاهداف السلوكية او مخرجات التعليم الأساسية		
ت	تفصيل الهدف السلوكي او مخرج التعليم	آلية التقييم
1	المجال المعرفي (المجال العقلي والادراكي)	تذكر المعلومات او الحقائق او المفاهيم او النظريات التي تعلمها سابقا
2	المجال الوجداني (المجال العاطفي او الانفعالي)	التقبل والانتباه مستوى الاستجابة اهمية المادة
3	المجال النفسي (مهاري او الحركي)	المحاكاة الاداء المهاري الاداء الطبيعي للمهارة الاداء الذي يتطلب التناسق

الفصل الأول والثاني من المحتوى العلمي لمقرر منظومات نقل القدرة						
مقدمة الى منظومات نقل القدرة + المبادئ الأساسية لأنظمة نقل القدرة				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	مقدمة عامة عن منظومات نقل القدرة، أنواعها، وتخطيط خط نقل الحركة (Power Train Layout) في المركبات (أمامي، خلفي، رباعي).	٢ ساعة	النظري	الأسبوع الأول
تقييم الأداء المختبري والتفاعل	تطبيق وتفكيك مباشر، عرض أجزاء مجسمة	ورشة عملي	التعرف على ورشة منظومات نقل القدرة، إجراءات السلامة المهنية، والتعرف الظاهري على مكونات خط نقل الحركة في مركبة حية.	٤ ساعة	العملي	
تقييم ذاتي + اختبار يومي	عرض تقديمي، شرح، أسئلة وأجوبة، مناقشة	محاضرة	الديناميكا والمبادئ الأساسية	٢ ساعة	النظري	الأسبوع الثاني
تقييم المهارة	مجسمات، تفكيك أجزاء	ورشة عملي	فحص المكونات واستبدال أجزاء الإعتاق	٤ ساعة	العملي	

الفصل الثالث من المحتوى العلمي لمقرر منظومات نقل القدرة						
ناقل الحركة اليدوي				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي	شرح القوانين، عصف ذهني	محاضرة	التروس ونسب النقل (Gears & Gear Ratios)	٢ ساعة	النظري	الاسبوع الثالث
تقييم الأداء الفردي	بيان عملي، لوحات توضيحية	ورشة عملي	صيانة قرص الاحتكاك وإعادة التجميع	٤ ساعة	العملي	
اختبار يومي	عرض فيديو، توضيحية	محاضرة	القابض والمزامن (Clutch & Synchronizer)	٢ ساعة	النظري	الأسبوع الرابع
تقييم العمل الجماعي	تطبيق على صندوق تعليمي	تعلم نشط	تفكيك صندوق السرعات وتشخيص أجزائه	٤ ساعة	العملي	
تقييم ذاتي	عرض تقديمي، مناقشة	محاضرة	التحليل التشغيلي وتقييم الأداء	٢ ساعة	النظري	الاسبوع الخامس
تقييم دقة القياس	تفكيك وإعادة تجميع	ورشة عملي	صيانة وعمرة صندوق السرعات اليدوي	٤ ساعة	العملي	



الفصل الرابع من المحتوى العلمي لمقرر منظومات نقل القدرة						
نقل الحركة الاوتوماتيكي				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي + اختبار يومي	مجسمات ثلاثية الأبعاد	محاضرة	محول عزم الدوران (Torque Converter)	٢ ساعة	النظري	الأسبوع السادس
تقييم الأداء الفردي	تطبيق مباشر على المركبة	ورشة عملي	صندوق التروس الإضافي (Double/Transfer Case)	٤ ساعة	العملي	
تقييم ذاتي	شرح آليات الحركة، مناقشة	محاضرة	المجموعات الكوكبية والتحكم (Planetary Gear Sets)	٢ ساعة	النظري	الأسبوع السابع
تقييم التقرير	تفكيك أجزاء المحول وفحصها	ورشة عملي	محول العزم الهيدروليكي (Torque Converter)	٤ ساعة	العملي	

الفصل الخامس من المحتوى العلمي لمقرر منظومات نقل القدرة						
ناقل الحركة المتغير باستمرار (CVT)				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي	شرح، عرض فيديو هات للمنظومة	محاضرة	ناقل الحركة ثنائي القابض (DCT)	٢ ساعة	النظري	الأسبوع الثامن
تقييم دقة العمل	استخدام العدد الهوائية	ورشة عملي	تفكيك أجزاء ناقل الحركة الأوتوماتيكي	٤ ساعة	العملي	
تقييم ذاتي + اختبار يومي	عرض تقديمي، مقارنة منظومات	محاضرة	ناقل الحركة المتغير باستمرار (CVT)	٢ ساعة	النظري	الأسبوع التاسع
تقييم المهارة الفنية	تنظيف وتتبع مسارات الزيت	ورشة عملي	منظومة السيطرة الهيدروليكية (Valve Body)	٤ ساعة	العملي	



الفصل السادس من المحتوى العلمي لمقرر منظومات نقل القدرة						
أنظمة توليد القدرة الهجينة				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي	عرض تقديمي، مناقشة التطور التكنولوجي	محاضرة	مقدمة في المركبات الهجينة (HEV)	٢ ساعة	النظري	الأسبوع العاشر
تقييم تقرير الورشة	تبديل مفاصل متساوية السرعة	ورشة عملي	عمود الإدارة والوصلات & Propeller Shaft (Joints)	٤ ساعة	العملي	
اختبار قصير	عرض تقديمي، تفاعل صفي	محاضرة	منظومات نقل الحركة الهجينة والكهربائية	٢ ساعة	النظري	الأسبوع الحادي عشر
تقييم العمل الجماعي	استخدام ساحبات التروس	ورشة عملي	تفكيك المجموعة الفرعية	٤ ساعة	العملي	

الفصل السابع والثامن من المحتوى العلمي لمقرر منظومات نقل القدرة						
تقنيات أنظمة ناقل الحركة الحديثة والمستقبلية في السيارات وصيانة وإصلاح أعطالها				الوقت		عنوان الفصل
طرق القياس	التقنيات	طريقة التدريس	العنوان الفرعي			التوزيع الزمني
تقييم ذاتي	شرح خصائص الزيوت	محاضرة	سائل ناقل الحركة (Transmission Fluid)	٢ ساعة	النظري	الأسبوع الثاني عشر
تقييم دقة الضبط	استخدام ساعة القياس (Dial)	تعلم نشط	معايرة وضبط التروس الفرعية	٤ ساعة	العملي	
تقييم العمل الجماعي	دراسة أعطال واقعية	تعليم قائم على المشكلات	استكشاف الأعطال وإصلاحها (Troubleshooting)	٢ ساعة	النظري	الأسبوع الثالث عشر
تقييم الأداء المختبري	تطبيق إجراءات السلامة	ورشة عملي	صيانة النوابض وأعمدة اللي & Springs (Torsion Bars)	٤ ساعة	العملي	
تقييم المشاركة	مناقشة أبحاث حديثة	عصف ذهني	التوجهات المستقبلية ودراسات حالة	٢ ساعة	النظري	الأسبوع الرابع عشر
تقييم التقرير النهائي	فحص وصيانة الملحقات	ورشة عملي	منظومات التعليق والملحقات (Suspension Systems)	٤ ساعة	العملي	
تقييم ختامي للنظري	مراجعة المادة العلمية	مناقشة مفتوحة	مراجعة عامة ومناقشة تقارير الطلبة	٢ ساعة	النظري	الأسبوع الخامس عشر
تقييم الأداء النهائي	تقييم شامل داخل الورشة	اختبار عملي	التقييم العملي النهائي ومناقشة المشاريع	٤ ساعة	العملي	

المحتوى العلمي

خارطة القياس المعتمدة

عدد الفقرات	الأهداف السلوكية					الأهمية النسبية	عناوين الفصول	المحتوى التعليمي
	النسبة							
	التقييم	التحليل	التطبيق	الفهم	المعرفة			
5	0%	10%	20%	40%	30%	10%	Introduction to Power Transmission Systems	الفصل الاول
5	10%	10%	30%	30%	20%	10%	Basic Principles of Power Transmission Systems	الفصل الثاني
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" Introduction "

What is a Power Transmission System?

Power transmission system: This is the collection of mechanical and electrical components that generate energy from its source and convert it into rotational motion at the wheels to propel the vehicle.

Its components vary depending on the vehicle type:

- **Traditional vehicles:** These begin with the internal combustion engine and end with the wheels.
- **Modern vehicles (hybrid and electric):** These also include electric motors, high-voltage batteries, and power inverters.

The main components of the system (in conventional cars):

1. **Power source (engine):** The engine generates rotary mechanical motion.
2. **Clutch or torque converter:** Connects and disconnects power between the engine and the transmission.
3. **Transmission/Gearbox:** Changes speed and torque ratios according to driving conditions.
4. **Drive shaft:** Transmits motion longitudinally from the gearbox to the axles (in rear-wheel and four-wheel drive).
5. **Differential group:** distributes motion to the wheels, allowing them to rotate at different speeds in turns.
6. **Axles:** Transfer torque directly to the wheels.

The Car consists of the following main components:

1. The engine.
2. The power transmission system (also referred to as the drivetrain or powertrain).
3. The metal structure (chassis or lower part of the car), which includes the steering system, suspension system, braking system, axles, wheels, and tires.
4. Car body (the upper part of the car).

Through these groups, we realize the importance of the power transmission system as one of the main groups and as a basic system in cars, which is responsible for transferring the power generated from the car engine at the engine flywheel and delivering it to the driving wheels in the car. Therefore, it is necessary to recognize the function of this system, its main components, and the different types of power transmission systems in cars that transfer power from the engine to the driving wheels (i.e., the different ways of driving vehicles).

Functions and Components of Automotive Power Transmission Systems

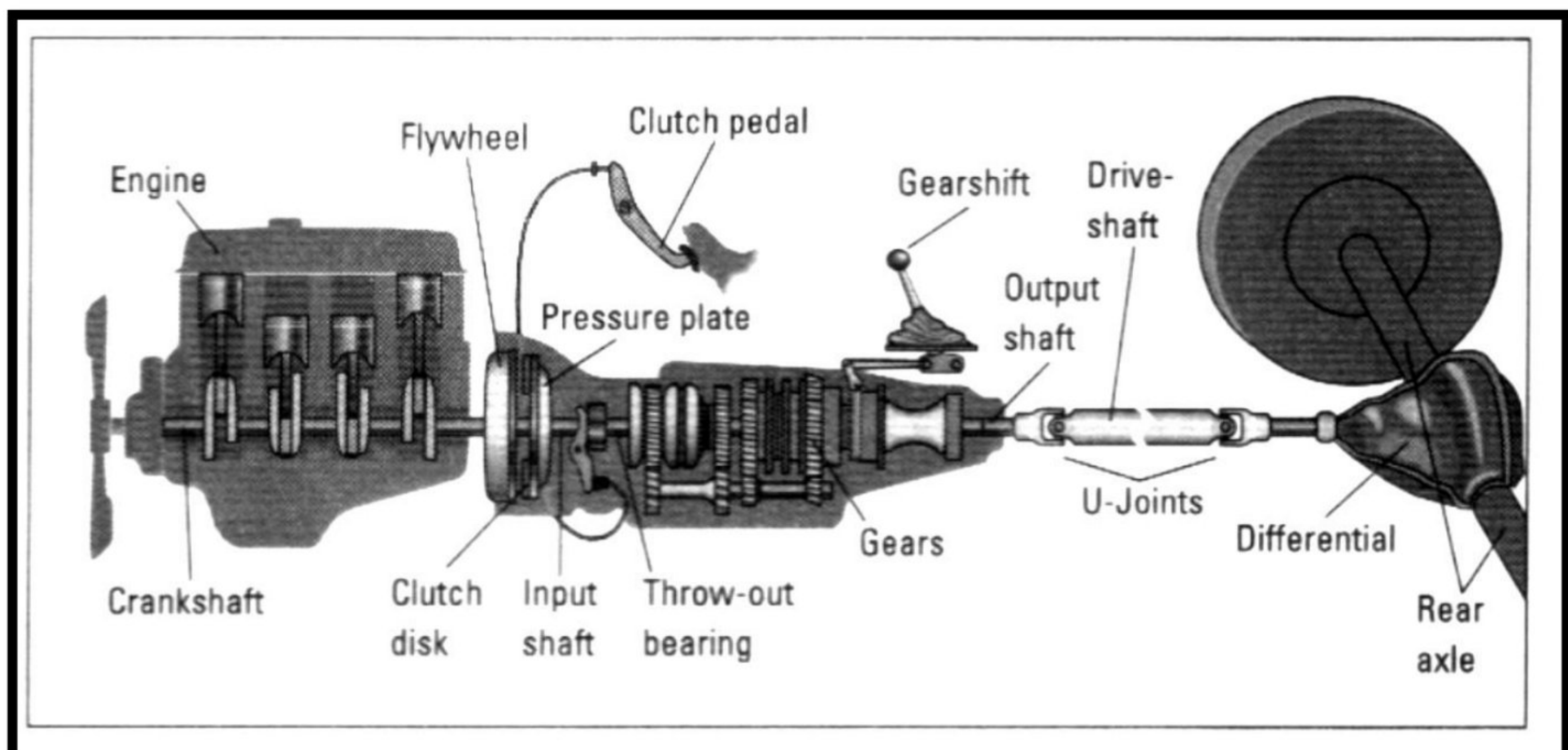
1. Function of Automotive Power Transmission System

The automotive power transmission system is designed to contain all the components that transfer the power generated by the engine from the flywheel (at the end of the crankshaft) to the vehicle's driving wheels. This is the primary function of the automotive power transmission system. It should be noted that the power transmission line begins at the engine flywheel and ends at the driving wheels.

2. Components of Automotive Power Transmission Systems

The automotive power transmission system (Figure 1) consists of the following main parts:

- **Engine:** the starting point, responsible for generating power.
- **Clutch:** responsible for connecting and disconnecting the flow of power from the flywheel.
- **Gear Box or Transmission:** the unit responsible for mechanically changing speeds and torque.
- **Drive Shaft and Joints:** transfer power from the gearbox to the final drive, called the driveshaft (in rear-wheel drive) or CV axles/spare shafts (in front-wheel drive).
- **Final Drive / Differential:** reduces the final speed and distributes power to the wheels.
- **Axles:** These are the means of transferring power from the final drive system to the drive wheels.
- **Driving Wheels:** the endpoint that receives power and converts it into motion that propels the vehicle along the road.



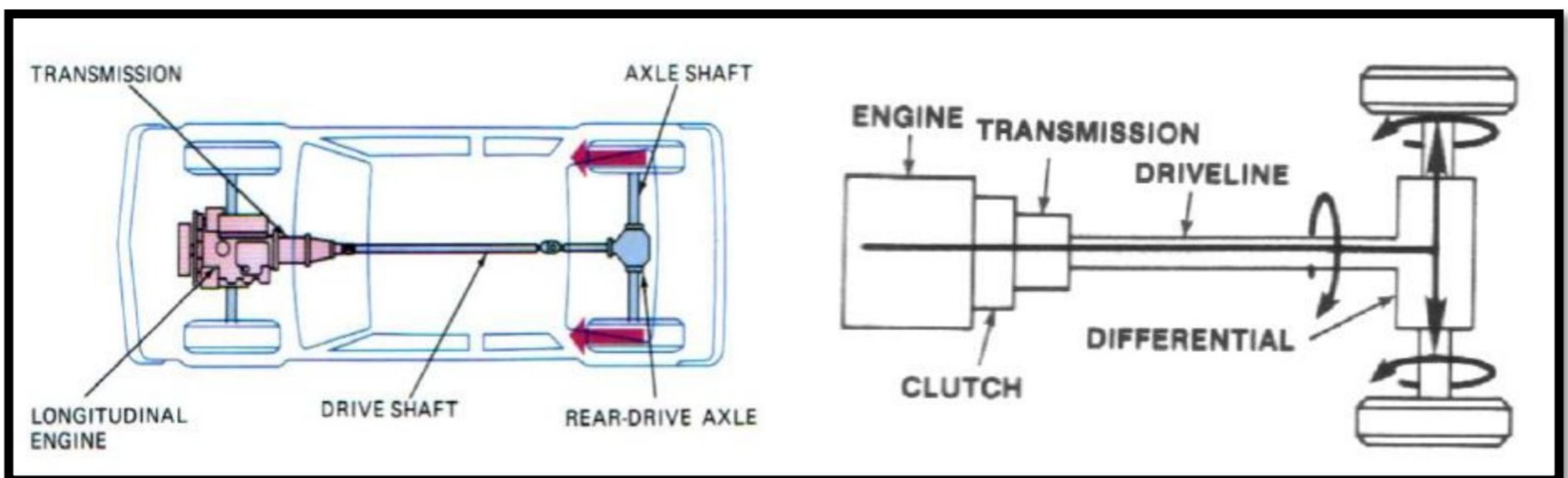
Automotive Drive Trains and Power Flow

Commonly used vehicle drive methods can be divided into three main configurations:

1. Rear-Wheel Drive (RWD) (The standard or conventional drive).
2. Front-Wheel Drive (FWD).
3. Four-Wheel Drive (4WD) and All-Wheel Drive (AWD).

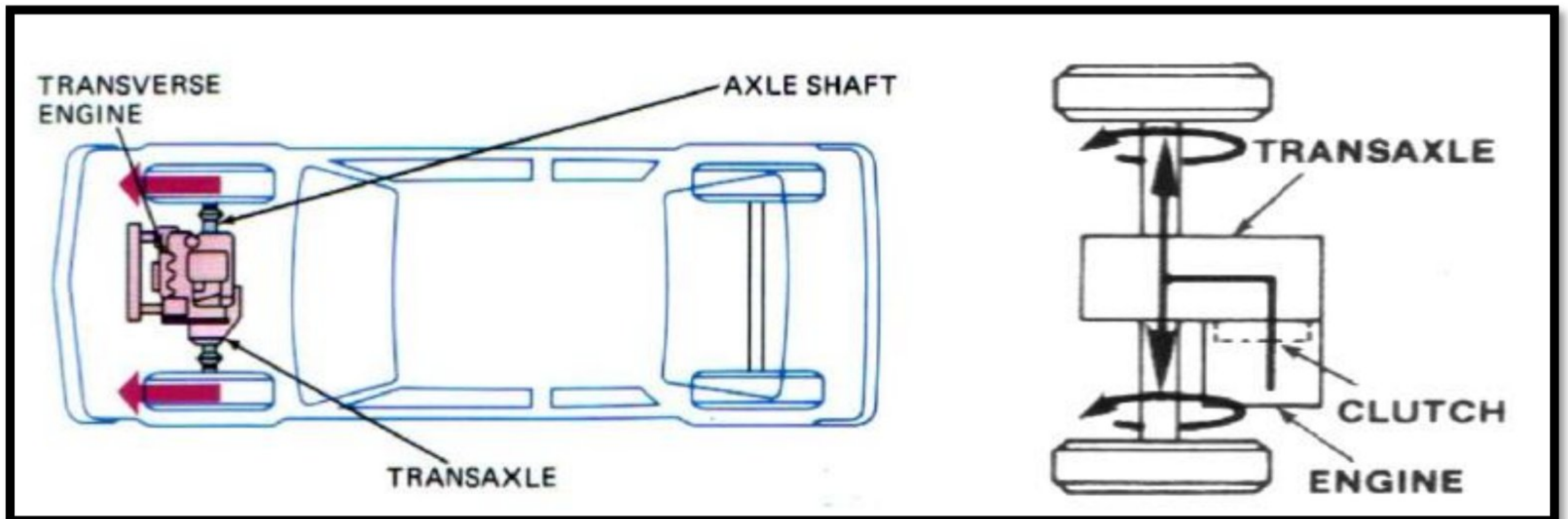
1. Rear-Wheel Drive (RWD) (Conventional, Standard, or Rear Drive)

In this method (Figure 2), the engine power (with the engine located at the front of the vehicle in a longitudinal position) is transmitted through the clutch to the manual transmission. It then flows to the final drive assembly via the articulated drive shaft (propeller shaft and its universal joints). Finally, the engine power ends at the vehicle's driving wheels (the rear wheels) through the rear axle drive shafts. The power flow path of the vehicle engine is illustrated in Figure 3 according to the arrows shown.



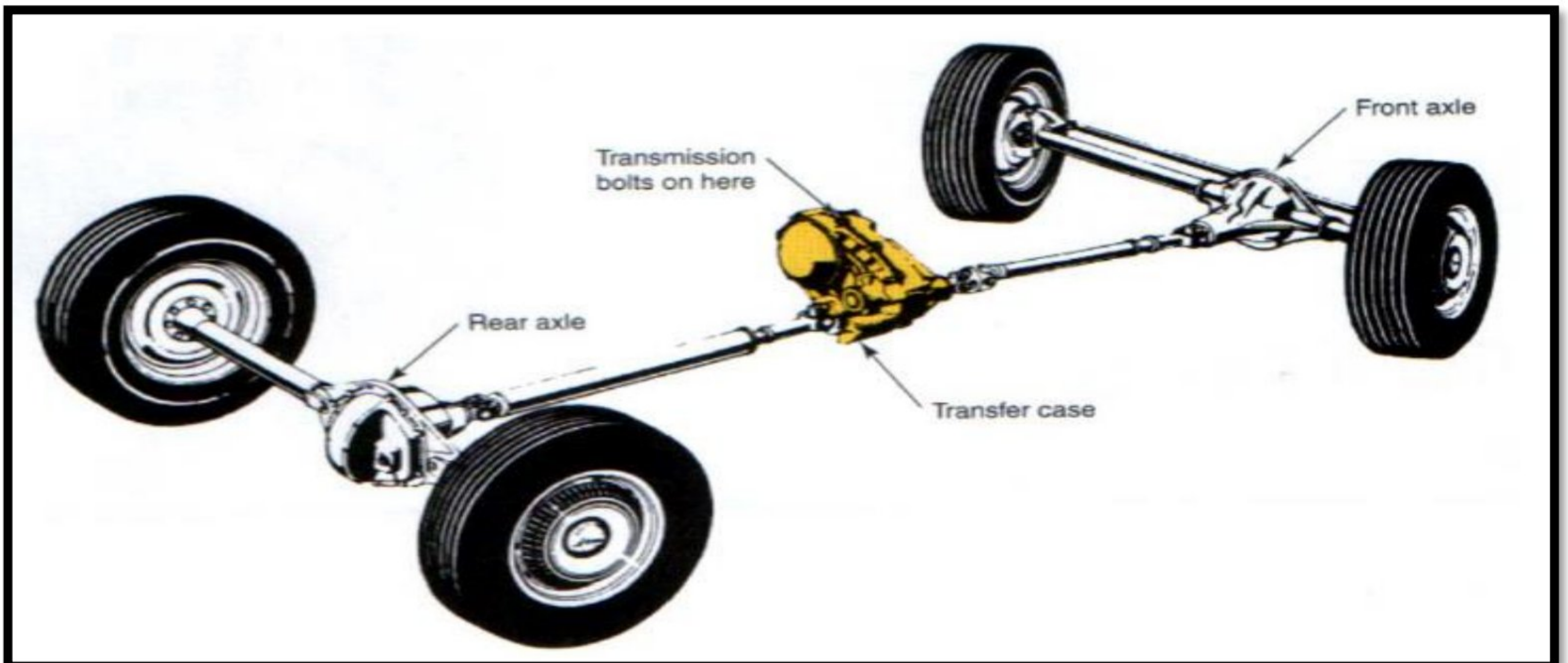
2. Front-Wheel Drive (FWD) (Front Traction)

In this configuration, as shown in Figure 4, the engine power (with the engine located at the front of the vehicle in a transverse layout, which is the most common layout for this method) is transmitted through the clutch to the manual transaxle assembly. It then goes to the front differential, and via the front axle drive shafts (half-shafts/axles), the engine power ends at the vehicle's driving wheels (the front wheels). It is worth noting here that there is no articulated drive shaft (propeller shaft). The power flow path of the vehicle engine is illustrated in Figure 5 according to the arrows shown.



3. Four-Wheel Drive (4WD) and All-Wheel Drive (AWD)

In this method, the engine power (with the engine located at the front of the vehicle) is transmitted, as shown in Figure 6 and Figure 7, through a system that combines front-wheel drive and rear-wheel drive features so that power can ultimately be transmitted to all driving wheels (both front and rear).



Basic principles of power transmission systems

When studying power transmission systems, the engine is the beating heart of the vehicle. To understand its performance and assess its efficiency, we cannot rely on arbitrary terminology. In this lecture, we will lay the foundation for understanding mechanical performance by examining the well-known engineering triad: **torque**, **speed**, and **power**. We will explore the physical concept of each, the mathematical equations that connect them, and how these mathematical concepts translate into the actual performance you experience and interact with in auto repair shops and on the road.

1. Torque - "Pulling and Rotating Force"

It is a measure of the rotational force produced by the engine components (piston, connecting rod, and crankshaft). **In automobiles, torque is responsible for a car's ability to accelerate, tow loads, and climb hills.**

Basic Mathematical Equation:

$$T = F * r$$

T: Torque, measured in Newton-meters (N.m) or (lb-ft).

F: The applied force, measured in Newtons (N) (which is the force resulting from the explosion of the fuel and the pressure on the engine piston).

r: Force arm or radius of rotation, measured in meters (m) (and in the engine it is represented by the length of the crankshaft arm).

2. Speed / Angular Velocity (N / ω)

In engines, we often measure speed in revolutions per minute (**RPM**), denoted by **N**. Mathematically, in physical equations, we use angular velocity ω in the unit (**rad/s**).

$$\omega = \frac{2\pi N}{60}$$

3. Horsepower (Power) - "Rate of Work Done"

Power is the rate of work done per unit time. In internal combustion engines, power is the direct result of combining torque with rotational speed .

The Mathematical Relationship Between the Three:

Mechanical power is the product of torque (T) and angular velocity (ω).

$$\text{Power} = \text{torque} * \text{angular velocity}$$

$$\text{Power} = T * \omega$$

$$\text{Power (watt)} = \frac{T * 2\pi N}{60}$$

$$\text{Power(HP)} = \frac{T * N}{7127}$$

Power conversions

1. *From HP to kW* $\rightarrow 1HP = 0.746 kW$
2. *From kW to HP* $\rightarrow 1kW = 1.341 HP$

Question: A sedan engine was tested on a dynamometer, and it was found that the engine generates a maximum **horsepower** of **150 hp** at a **rotational speed** of **5000 RPM**. Calculate the **torque** generated by the engine at this speed in geometric units (**N.m**).

Example 2.1: A hybrid car engine is connected to a dynamometer, and the engine registers a **torque** of **250 N.m** at a **rotational speed** of **3000 RPM**. Calculate the **power output** of the engine in **horsepower (HP)**.

Solution:

$T = 250 \text{ N.m}$

$N = 3000 \text{ RPM}$

$$Power = \frac{T * N}{7127}$$

$$Power = \frac{250 * 3000}{7127}$$

$$\therefore Power = 105.2 \text{ HP}$$

The engine's power at this point of rotation is **105.2 HP**.

Units of measurement, power transmission efficiency in vehicles

In the world of automotive engineering, there is no room for approximations. When diagnosing a fault, designing a mechanical part, or reading a workshop manual, you will encounter different measurement systems (such as the International System of Units (SI) and the Imperial/American System). Failure to understand these units or incorrect conversions can lead to mechanical disasters or completely misdiagnosis. Furthermore, power generation within the engine is worthless if that power is lost on its way to the wheels via the drivetrain.

First: Basic Units of Measurement in Cars (Metrics vs Imperial)

A car engineer needs to master the following table, which summarizes the most important physical quantities and their units of measurement in the two common systems:

physical quantity	International System of Units (SI)	The unity of the American/imperial system
Torque	N.m	lb. ft
Power	kW	American horsepower (HP)
Rotational speed (ω)	rad/s	Revolutions per minute (RPM)
Pressure (such as tire or engine pressure)	bar or kilopascal (kPa)	Pounds per square inch (PSI)
Displacement	Liter (L) or cubic centimeter (cc)	cubic inch (CID - cu\ in)

Second: Power Transmission Efficiency in Vehicles

- **The concept of transmission efficiency (η):** The power generated by the engine does not reach the wheels in its entirety. There are mechanical and thermal losses within the gearbox, drive shaft, differential, and bearings.

Mechanical efficiency (η): is defined as the ratio of power output (reaching the wheels) to power input (generated by the engine).

$$\eta = \frac{Power_{Wheel}}{Power_{Engine}} * 100\%$$

- **Where Does the Lost Power Go? (Drivetrain Losses)**

The power loss in two-wheel drive (2WD) vehicles ranges from 10% to 15%, while in all-wheel drive (AWD/4WD) vehicles it can reach 20% or more due to the increased number of moving parts. This power is dissipated in the form of:

- Mechanical friction:** between the teeth of the gears inside the transmission and differential.
- Oil viscosity resistance:** The movement of gears within thick transmission oil consumes energy (called hydraulic losses).
- Torque converter:** In a conventional automatic transmission, power is transmitted via fluid (hydraulics), resulting in a noticeable power loss before the lock-up stage.

Example 2.2: A modern car has an engine that generates **120 kW**. Given that the efficiency of this car's transmission system is $\eta = 85\%$ due to friction losses, what are the possible solutions?

1. Calculate the actual power delivered to the wheels in kilowatts (kW).
2. Calculate the power lost as heat in horsepower (HP).

Solution

1. Calculating the power delivered to the wheels:

$$Power_{Wheel} = Power_{Engine} * \eta = 120 * 0.85 = 102 \text{ kW}$$

So, only 102 kW actually reached the car to power it.

2. Calculating lost power and converting it to (HP):

First, we calculate the power loss in kilowatts:

$$Power_{Loss} = Power_{Engine} - Power_{Wheels} = 120 - 102 = 98 \text{ kW}$$

Secondly, we convert this lost power into horsepower (HP):

$$Power_{Loss (HP)} = 98 * 1.341 = 131.41 \text{ HP}$$

Conclusion: The transmission system in this car dissipated the equivalent of 131.41 horsepower in the form of heat and friction before the energy reached the ground!

Example 2.3: A four-wheel drive (4WD) vehicle whose engine generates up to **290 HP**. When tested on the chassis dynamometer, it was found that the power delivered to the wheels was only **226.2 HP** due to friction losses in the differentials and driveshaft.

1. Calculate the mechanical efficiency (η) of the power transmission system.
2. Calculate the amount of power lost in kilowatts (kW).

Solution

1. Calculating mechanical efficiency (η):

$$\eta = \frac{Power_{Wheel}}{Power_{Engine}} * 100\% = \frac{226.2}{290} * 100\% = 78\%$$

وهي كفاءة منطقية جداً لسيارات الدفع الرباعي بسبب كثرة الأجزاء الدورانية

2. First, calculate the power loss in HP, then convert it to kW:

$$Power_{Loss (HP)} = 290 - 226.2 = 63.8 \text{ HP}$$

$$Power_{Loss (kW)} = 63.8 * 0.746 = 47.6 \text{ kW}$$

Example 2.4: While an electric car is decelerating, the wheels rotate the mechanical generator with a **torque** of **180 N·m** at a **speed** of **2000 RPM**.

1. Calculate the mechanical power input to the generator in (HP).
2. Given that the generator's efficiency in converting mechanical energy to electrical energy is $\eta = 90\%$, calculate the electrical power output that charges the battery in (kW).

Solution

1. Calculating the mechanical **power input** to the generator (HP):

$$Power = \frac{T * N}{7127} = \frac{180 * 2000}{7127} = 50.51 \text{ HP}$$

2. Calculating the electrical **power supplied** to the battery (kW):

$$Power_{input} (kW) = 50.51 * 0.746 = 37.68 \text{ kW}$$

$$\eta = \frac{Power_{output} (kW)}{Power_{input} (kW)}$$

$$Power_{output} (kW) = Power_{input} (kW) * \eta = 37.68 * 0.9 = 33.91 \text{ kW}$$

" Manual Transmissions"

Manual Transmissions

The engine (power point) of a vehicle has a specific range of torque and rotational speed (RPM). Since road conditions vary greatly—from very high torque when starting and climbing, to high speeds and low torque when driving on highways—the engine cannot meet these demands directly and efficiently.

This is where the need for a manual transmission arises. It is a mechanical system that converts engine power and adapts it to driving conditions by controlling the torque and speed delivered to the drive wheels.

Operating Principle of a Manual Transmission

A manual transmission is fundamentally based on gear meshing at power transmission points. A conventional transmission (longitudinal or transverse shaft) consists of three main shafts:

1. **Input Shaft/Clutch Shaft:** This shaft is directly connected to the clutch and transmits power from the engine at the same speed.
2. **Countershaft/Layshaft:** This shaft contains a set of fixed gears mounted on it and rotates in tandem with the input shaft.
3. **Output Shaft/Main Shaft:** This shaft carries the different speed gears. These gears rotate freely above the output shaft (using bearings) and only transmit power to the shaft when engaged by the synchronizer assembly.

Power Flow Mechanism:

1. In neutral, the output shaft gears rotate freely without the shaft itself rotating.
2. When a specific speed is selected, the gear corresponding to that speed is mechanically locked with the output shaft, forcing the shaft to rotate at its speed, and then the power is transferred directly to the drive shaft or wheels.

Gear ratios and selection

The physical principle of gear ratios: The laws of mechanics govern gear ratios based on the number of teeth (N) or diameters (D). The gear ratio (i) is calculated using the following relationship:

$$i = \frac{N_1}{N_2}$$

N_1 : Number of teeth on the driven (dependent) gear.

N_2 : Number of teeth on the leading gear.

This ratio directly controls the torque (T) and angular velocity (ω):

$$i = \frac{T_1}{T_2} = \frac{\omega_2}{\omega_1}$$

Gear Selection Criteria:

When designing a transmission, gear ratios are selected based on the engine torque curve and vehicle weight:

- **Low gears (1st and 2nd):** The gear ratio is large (e.g., $i = 4:1$). This means reduced speed and significantly increased torque to overcome the vehicle's inertia during acceleration.
- **Intermediate gears (3rd and 4th):** The ratio gradually approaches (1:1), and is called Direct Drive (where the engine speed is equal to the output shaft speed).
- **High gears (5th and 6th):** The ratio is less than one (e.g., $i = 0.8:1$), and is called Overdrive. Here, the output shaft rotates at a higher speed than the engine speed, which reduces fuel consumption and engine noise at highway speeds.

Clutch Operation and Synchronization

First: Clutch Operation

The clutch is the link between the engine and the transmission.

- **When the clutch pedal is pressed:** The pressure plate moves away from the clutch disc, completely disconnecting the power flow. This allows the driver to change gears without damaging the gear teeth.
- **When the pedal is gradually released:** The clutch disc gradually returns to its original speed, allowing the engine speed to equalize with the input shaft speed.
- **Second: Synchronization Mechanism**
- In modern transmissions, helical gears are used, which are constantly engaged. The problem lies in the fact that the gear to be engaged and the output shaft rotate at different speeds. To avoid collisions, we use a synchronizer (or synchromesh):
- **Synchronization Ring:** A ring, usually made of brass, containing an inner cone and small teeth.
- **Operating Principle:** When the gear selector is moved, the fork pushes the engagement sleeve towards the desired gear.
- **Conical Friction:** Before the teeth are fully engaged, the sleeve presses against the brass synchronization ring, which in turn presses against the conical part of the gear. This friction causes the gear speed and shaft speed to be exactly equal within fractions of a second.

- **Smooth Engaging:** Once the speeds are matched, the sleeve smoothly slides over the gear teeth, engaging without any noise or violent mechanical effort.

Example calculation of "Gear Ratio Calibration"

Example 3.1: A small saloon car, its engine rotates at its maximum torque point at a **speed of 3000 rpm**. If the number of teeth on the input gear (driver gear) for first gear is $N_2 = 12$ teeth, and the number of teeth on the output gear (driven gear) is $N_1 = 42$ teeth.

1. Calculate the gear ratio (i) for this speed.
2. Calculate the output shaft rotation speed (ω_1).
3. If the motor **input torque** is **150 N.m**, calculate the output torque from the output shaft (neglecting losses).

Solution

1. Calculating the gear ratio (i):

$$i = \frac{N_1}{N_2} = \frac{42}{12} = 3.5$$

النسبة هي 3.5:1، وهي نسبة تخفيض نموذجية للترس الأول

2. Calculating the output shaft speed:

$$i = \frac{\omega_2}{\omega_1} \rightarrow \omega_1 = \frac{\omega_2}{i} = \frac{3000}{3.5} = 857.14 \text{ rpm}$$

3. Calculating the output torque:

$$i = \frac{T_1}{T_2} \rightarrow T_1 = i * T_2 = 3.5 * 150 = 525 \text{ N.m}$$

" Automatic Transmissions"

Automatic Transmissions

The automatic transmission is considered one of the most significant technological advancements in automotive engineering. Its primary function is to transfer power and torque from the engine to the wheels fully automatically, without requiring driver intervention to change gears or press the clutch pedal. This system relies on a continuous balancing of vehicle speed and engine load to select the optimal gear ratio, ensuring smooth performance and greater driving comfort, especially in congested traffic conditions.

Types of Automatic Transmissions

Automatic transmissions come in a variety of technical designs based on their power transmission mechanism, the most common of which in the current automotive market are:

1. Conventional Automatic Transmission with Torque Converter (Hydraulic Automatic-Torque Converter)

Concept: This is the most reliable and classic system. It does not use a dry mechanical clutch but relies on a hydraulic torque converter to transmit engine power to the transmission via fluids (hydraulic oil).

Application: Widely used in SUVs, trucks, and large sedans due to its high torque capacity.

2. Dual-Clutch Transmission (DCT)

Concept: Combines the efficiency of a manual transmission with the convenience of an automatic. It features two separate clutches; one controls the odd-numbered gears (1, 3, 5) and the other the even-numbered gears (2, 4, 6). When first gear is engaged, second gear is already in place and pre-engaged, resulting in shift times that are fractions of a second.

Application: Very common in sports cars and high-performance vehicles (such as the Volkswagen DSG and Ford Powershift groupsets) due to its exceptionally fast shifting.

3. Continuously Variable Transmission (CVT)

Concept: It does not use traditional gears, but rather two variable-diameter pulleys connected by a metal belt/chain, providing an infinite number of smoothly changing gear ratios without any "hair" or shifting sensation.

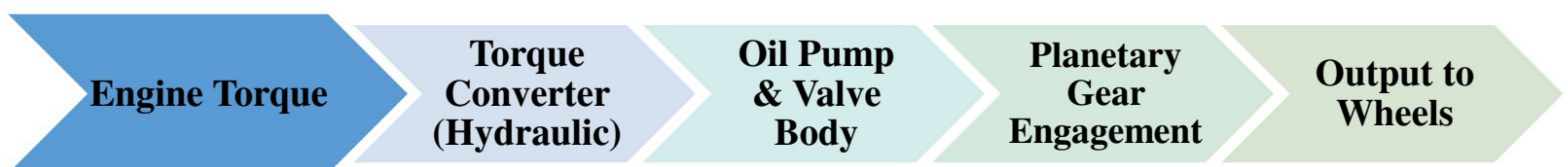
Application: Primarily focused on fuel efficiency, it is common in modern Japanese cars (such as Toyota, Nissan, and Honda).

The basic components of an automatic transmission (conventional type)

An automatic transmission consists of a complex mechanical, hydraulic, and electronic system working in perfect harmony:

1. **Torque converter:** Located between the engine and the transmission, it acts as a clutch. It consists of a pump, turbine, and stator.
2. **Planetary gear set:** The mechanical system responsible for generating different gear ratios (reverse and forward). It consists of a sun gear, planet gears, and ring gear.
3. **Clutches and belts:** Friction elements that engage or disengage specific parts of the planetary gear set to change the gear ratio (speed).
4. **Valve body:** Known as the "brain of the transmission," it is a hydraulic labyrinth that directs pressurized oil to the appropriate clutches and belts to activate the desired gear.
5. **The oil pump** is the heart of the system, generating the hydraulic pressure necessary to operate the valves and lubricate and cool the internal components.
6. **The transmission control module (TCM)** receives signals from sensors (such as the vehicle speed sensor and the throttle position sensor) and sends electrical commands to the solenoids to switch at the optimal time.

How an automatic transmission works



1. **Hydraulic Power Transmission:** As the engine rotates, the torque converter pump spins, forcing oil towards the turbine. This causes the turbine, which is connected to the main transmission shaft, to rotate.
2. **Analysis and Decision-Making:** While in motion, the vehicle's ECU/TCM continuously transmits data about the vehicle's speed and load.
3. **Hydraulic Steering:** Based on this data, the ECU sends electrical pulses to open or close the solenoids within the valve body.
4. **Gear Change:** Pressurized oil flows to engage a specific clutch or release a belt, locking one of the planetary gear components (e.g., locking the sun gear and making the ring gear the driver). This results in a new gear and different torque, which is transmitted directly to the drive shaft or wheels.

Practical and computational examples

We focus on calculating the gear ratios in a planetary gear set, which is governed by the following general equation:

$$(N_R * \omega_R) + (N_S * \omega_S) = (N_R + N_S) * \omega_c$$

N_R : Number of teeth on a ring gear.

N_S : Number of teeth on a sun gear.

ω_R : Angular velocity of a ring gear.

ω_S : Angular velocity of a sun gear.

ω_c : Angular velocity of a planetary gear carrier.

Example 4.1: Calculating the ratio of the first speed gear (fixing the ring gear)

In a simple planetary gear set for an automatic transmission, if the sun gear has $N_S = 24$ teeth and the ring gear has $N_R = 72$ teeth, and the **ring gear is fixed** by a brake band, and the **sun gear** is the input gear from the engine at **2000 rpm**, find the **output speed of the planetary gear** and calculate the **gear ratio**.

Solution

$$N_S = 24$$

$$N_R = 72$$

$$\omega_S = 2000 \text{ rpm}$$

The **ring gear is fixed**, $\therefore \omega_R = 0$

1. The output speed of the planetary gear (ω_c)

$$\begin{aligned}(N_R * \omega_R) + (N_S * \omega_S) &= (N_R + N_S) * \omega_c \\ (72 * 0) + (24 * 2000) &= (72 + 24) * \omega_c \\ 0 + 48000 &= 96 * \omega_c \rightarrow \omega_c = \frac{48000}{96} = 500 \text{ rpm}\end{aligned}$$

2. Calculating the gear ratio:

$$\text{Gear ratio} = \frac{\omega_{input}}{\omega_{output}} = \frac{\omega_S}{\omega_c} = \frac{2000}{500} = 4:1$$

Example 4.2: Calculating the reverse gear ratio

Using the same previous gear set ($N_S = 24$, $N_R = 72$). If the **planetary gear carrier** is secured by a clutch, and the **sun gear** is made the input from the engine at **1500 rpm**. Find the speed and direction of rotation of the **ring gear** (Output), and calculate the **gear ratio**.

Solution

$$N_S = 24$$

$$N_R = 72$$

$$\omega_S = 1500 \text{ rpm}$$

The carrier is fixed, $\therefore \omega_c = 0$

1. The speed and direction of rotation of the **ring gear** (Output), (ω_R)

$$(N_R * \omega_R) + (N_S * \omega_S) = (N_R + N_S) * \omega_c$$

$$(72 * \omega_R) + (24 * 1500) = (72 + 24) * 0$$

$$72 * \omega_R + 36000 = 0 \rightarrow 72 * \omega_R = -36000 \rightarrow \omega_R = \frac{-36000}{72}$$

$$= -500 \text{ rpm}$$

Note the negative signal: The negative signal means that the ring gear (output) rotates in the opposite direction of the motor's rotation (input), and this is exactly what makes the car move backward (reverse).

2. Calculating the gear ratio for reverse speed:

$$\text{Gear ratio} = \frac{\omega_{\text{input}}}{\omega_{\text{output}}} = \frac{\omega_S}{\omega_R} = \frac{1500}{500} = 3:1$$

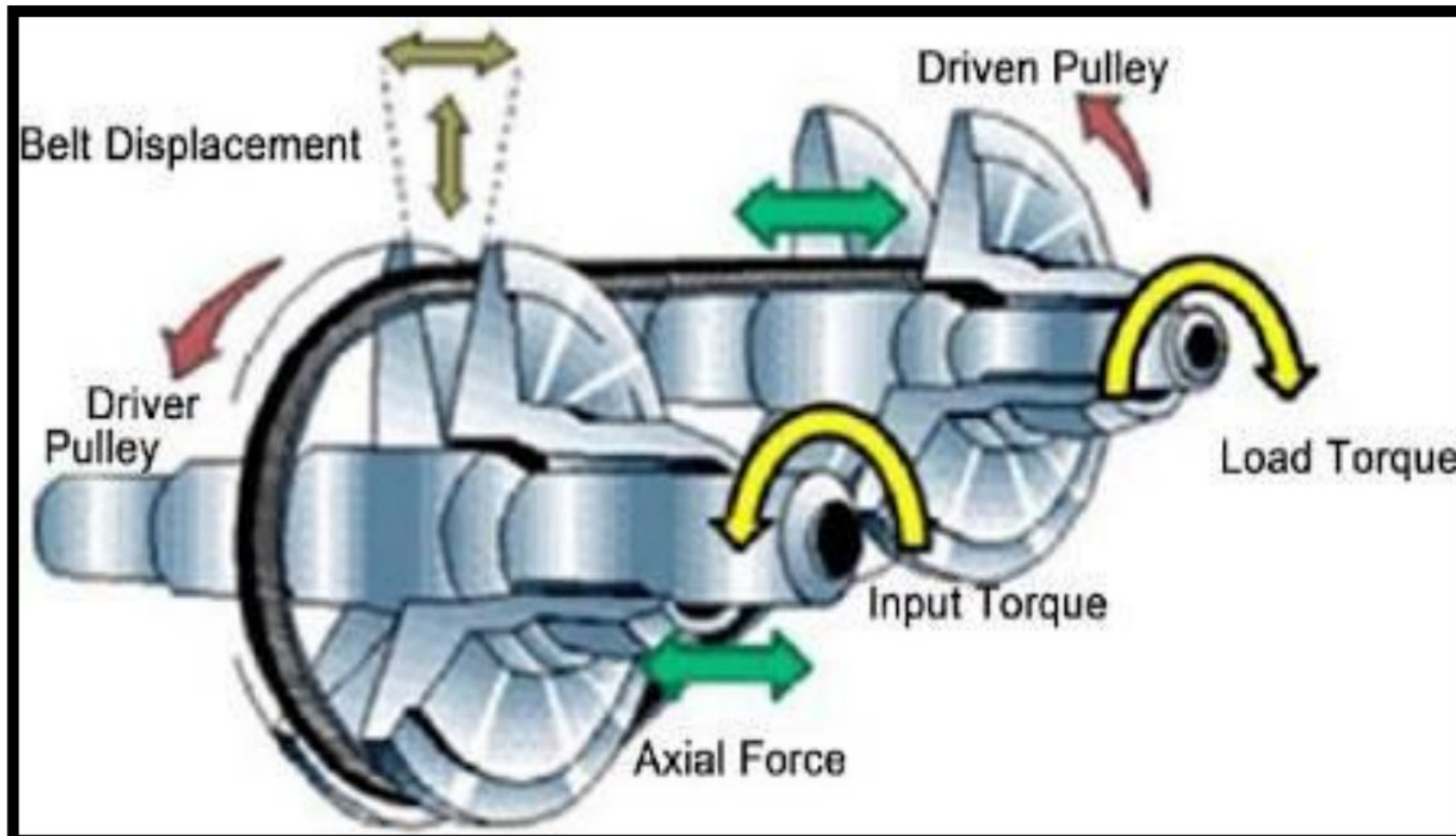
" Continuously Variable Transmissions (CVTs)"

In conventional transmissions (manual or planetary automatic), gear ratios are limited to a specific number of gears, such as 5, 6, or 8. This restriction forces the engine to shift between specific "steps," often pushing it out of its optimum efficiency range.

As for the continuously variable transmission (CVT), it is a system that allows for a smooth and infinite change in the transmission ratio between two extreme values (lower and upper), without the presence of traditional interlocking gears for forward speeds. This ensures the engine maintains its peak torque or fuel efficiency under various driving conditions.

Operating Principle of a Transmission

The most common type in modern cars relies on a variable pulley system and a robust Bright (Pulley-and-Belt System):



شكل (١): مخطط هندسي لآلية عمل بكرات الـ CVT والحزام المعدني

- **Driver/Primary Pulley:** Connects to the motor side (Input Torque).
- **Driven/Secondary Pulley:** Connects to the drive wheels side (Load Torque).
- **Push Belt/Chain:** Transmits torque between the two pulleys via friction and groove compression forces.

Each pulley consists of two opposing cones that move towards and away from each other via an electronically controlled axial force (hydraulic force) via the control unit (TCU):

- **At low speed and high torque:** The cones of the driving pulley move away (its effective diameter decreases), while the cones of the driven pulley

move closer together (its effective diameter increases). The result: a high gear ratio.

- **At high speed (overdrive):** The cones of the driving pulley move closer together (its diameter increases), while the cones of the driven pulley move away together (its diameter decreases). The result: a high gear ratio.

We use the basic laws of pulley motion transmission:

$$\text{Gear ratio} = \frac{N_{in}}{N_{out}} = \frac{R_{out}}{R_{in}}$$

Where **N** is the **rotational speed (rpm)**, and **R** is the **effective radius** of the pulley.

Example 5.1: Calculating range and overall percentages

In a CVT transmission, the effective radius of the driving pulley varies R_{in} from **30 mm** a minimum to **900 mm** a maximum. Similarly, the effective radius of the driven pulley varies R_{out} from **40 mm** a minimum to **120 mm** a maximum. If the engine's constant speed at peak efficiency is **2400 rpm**, calculate:

1. The maximum and minimum transmission ratios (Ratio Range).
2. The maximum and minimum output shaft rotational speeds (N_{out}).

Solution

$$R_{in,min} = 30 \text{ mm}$$

$$R_{in,max} = 900 \text{ mm}$$

$$R_{out,min} = 40 \text{ mm}$$

$$R_{out,max} = 120 \text{ mm}$$

$$N_{in} = 2400 \text{ rpm}$$

1. Calculating ratios (Gear Ratios):

- ✚ The highest ratio (maximum torque/launch) occurs when the diameter of the lead is as small as possible and the driven is as large as possible:
النسبة الأكبر (العزم الأقصى / الانطلاق) تحدث عندما يكون قطر القائدة أصغر ما يمكن والمقادة أكبر ما يمكن:

$$i_{max} = \frac{R_{out,max}}{R_{in,min}} = \frac{120 \text{ mm}}{30 \text{ mm}} = 4.0$$

- ✚ The smaller ratio (maximum speed/overdrive) occurs when the diameter of the lead is as large as possible and the driven as small as possible:
النسبة الأصغر (السرعة القصوى / Overdrive) تحدث عندما يكون قطر القائدة أكبر ما يمكن والمقادة أصغر ما يمكن:

$$i_{min} = \frac{R_{out,min}}{R_{in,max}} = \frac{40 \text{ mm}}{90 \text{ mm}} \approx 0.444$$

2. Calculating the output shaft speed (N_{out}):

- ✚ Minimum output rotational speed (at startup):

$$N_{out,min} = \frac{N_{in}}{i_{max}} = \frac{2400}{4.0} = 600 \text{ rpm}$$

✚ Maximum rotational speed of the output (during circumambulation):

$$N_{out,max} = \frac{N_{in}}{i_{min}} = \frac{2400}{0.444} = 5405.4 \text{ rpm}$$

Advantages and disadvantages of continuously variable transmission (CVT)

Advantages		Disadvantages	
Improved fuel economy	تحسين الاقتصاد في الوقود	Limited torque tolerance	محدودية تحمل العزم العالي
Smooth acceleration	تسارع سلس	Maintenance costs	تكلفة الصيانة
Comfortable driving experience	راحة القيادة	Requirement for special oils	الحاجة إلى زيوت خاصة
High operational efficiency	كفاءة تشغيلية عالية	Unusual acceleration feel	الإحساس غير التقليدي أثناء التسارع
Reduced emissions	تقليل الانبعاثات	Sensitivity of the timing belt	حساسية الحزام المعدني

Applications of CVTs in modern vehicles

Current applications in the market can be classified into three main axes:

- 1. Economy Passenger Cars:** Companies such as Nissan, with its Xtronic CVT systems, Toyota, with its Direct Shift-CVT (which integrates a physical gear first for rapid acceleration and then switches to pulleys), and Honda, are among the most reliant on it in saloon cars (such as Altima, Corolla)
- 2. Hybrid Vehicles:** Toyota uses a special system called e-CVT (like the Prius and Camry hybrids). A scientific note for students: The e-CVT never uses pulleys or a metal belt! Instead, it relies on a planetary gear set that connects the engine to two electric generators. The transmission ratio is electrically controlled by balancing the speed of the generators and the engine. It is one of the most engineering-wise successful systems and has the fewest failures.
- 3. Lightweight four-wheel drive vehicles (Crossovers/Compact SUVs):** Subaru uses it under the name Lineartronic CVT, where it replaced the traditional rubber or metal belt with a very thick metal (Chain) to increase the ability to withstand continuous four-wheel drive torque.

" Hybrid Powertrain Systems"

Hybrid vehicles represent a crucial and essential transitional step between conventional internal combustion engine (ICE) vehicles and fully electric vehicles (BEVs). Given the global and Iraqi trend towards reducing carbon emissions and conserving fossil fuels, the need has arisen to design a system that combines the torque efficiency of electric motors at low speeds with the long range of gasoline or diesel engines at high speeds.

Introduction to Hybrid Vehicles

A hybrid vehicle (HEV) is a vehicle that uses two or more power sources to generate motion. The most common system combines:

1. **An internal combustion engine (ICE):** running on gasoline or diesel (often using the Atkinson cycle for increased thermal efficiency).
2. **An electric motor/generator:** powered by a high-voltage battery (HV battery).

Hybridization Levels

- ✚ **Micro Hybrid:** Equipped with a stop-start system to automatically shut off the engine when the vehicle is stationary.
- ✚ **Mild Hybrid (MHEV):** A small electric motor (typically 48 volts) assists the conventional engine and cannot move the vehicle on its own.
- ✚ **Full Hybrid (HEV):** The vehicle can travel a limited number of distances on electric power alone.
- ✚ **Plug-in Hybrid (PHEV):** Equipped with a large battery that can be charged from an external electrical outlet.

The basic components of hybrid power generation systems

The hybrid power system consists of the following main components:

1. **Internal Combustion Engine (ICE):** This is the heat source for power.
2. **Motor/Generator (MG):** This converts electrical energy into mechanical energy (propulsion) or vice versa (charging during regenerative braking).
3. **High-Voltage Battery Pack:** This is the electrical energy storage tank (often lithium-ion or nickel-metal hydride, NiMH).
4. **Inverter/Converter:** This converts the direct current (DC) from the battery to alternating current (AC) for the electric motor and controls the voltage and frequency.
5. **Power Control Unit (PCU):** This is the "brain" of the vehicle, managing the flow of power between the motor and battery according to driving conditions.
6. **Power Split Device/Hybrid Transmission:** This is a planetary gear set that combines the torque of both motors.

How Hybrid Power Generation Systems Work (Operating Modes & Architecture)

Hybrid systems are classified into three main types based on how their components are mechanically and electrically connected:

✚ Series Hybrid

Mechanism: The internal combustion engine is not connected to the wheels at all. Its function is limited to driving the generator to produce electricity. This electricity is used either to charge the battery or to power the electric motor, which drives the wheels directly.

✚ Parallel Hybrid

Mechanism: Both engines (electric and conventional) are connected to the transmission and can drive the wheels together or separately.

✚ Series-Parallel Hybrid/Power-Split

Mechanism: The most efficient system (such as the Toyota THS). Thanks to planetary gears, the system can operate in series or parallel mode simultaneously, with the power from the combustion engine divided between the wheels and the generator to charge the battery.

Advantages and disadvantages of hybrid vehicles

Advantages		Disadvantages	
Significant fuel economy	اقتصاد هائل في الوقود	Mechanical and electrical complexity	التعقيد الميكانيكي والكهربائي
Regenerative braking	الكبح التجديدي	High initial cost	التكلفة الابتدائية العالية
Instant torque	عزم دوران فوري	Excess weight	الوزن الزائد
Reduced emissions	تقليل الانبعاثات	Battery maintenance costs	تكلفة صيانة البطارية

" Transmission Maintenance and Troubleshooting"

The transmission is the driving force of a vehicle; it is responsible for efficiently transferring torque and power from the engine to the wheels, ensuring vehicle stability and fuel economy. Understanding the technology, maintenance, and troubleshooting of this system is just as important as the design of the engine itself, as most complex mechanical and electrical malfunctions today are concentrated in this vital component.

Basic Maintenance Procedures for Different Transmission Types

Maintenance requirements vary depending on the engineering design of each transmission. Here, we will focus on four main types:

1. Manual Transmission (MT)

Maintenance is relatively simple due to the limited number of electronic components:

- ✚ **Oil Check and Change:** This usually requires high-viscosity gear oil (such as 75W-90). Checking is done using the fill plug.

- ✚ **Clutch System:** Check the pedal free play and ensure there are no leaks in the master cylinder or slave cylinder in the hydraulic systems.

2. Conventional Automatic Transmission (AT)

This relies on hydraulics and electronic control (solenoid valves):

- ✚ **ATF Filter and Fluid Replacement:** This requires removing the oil pan, cleaning the metal shavings collector magnet, and replacing the oil pan gasket.

- ✚ **Software Update (Software Flash):** In modern cars, routine maintenance includes checking for software updates to the Transmission Control Module (TCM) to address transmission issues.

3. Continuously Variable Transmission (CVT):

Relies on variable-diameter pulleys and a steel belt:

- ✚ **Value is very sensitive:** It requires specialized CVT fluid on a very strict schedule (often every 40,000 to 60,000 km). Neglecting this leads to premature pulley wear.

- ✚ **Fluid Cooling Check:** Ensure the oil cooler is functioning properly, as heat is the primary enemy of the CVT.

4. Dual Clutch Transmission (DCT/DSG):

Combines manual and automatic transmission mechanics:

- ✚ **Clutch Type (Dry or Wet):** Wet DCTs require regular oil and filter changes to protect the clutches from burning out, while dry DCTs require monitoring clutch wear using diagnostic tools (scanners).

Common transmission problems and their solutions

Transmission malfunctions are classified as mechanical, hydraulic, or electrical. Here is a summary table as a quick diagnostic matrix:

No.	Symptom	Potential Cause	Recommended Solution
1	Gear slipping	Low oil level or worn friction clutches.	Topping up the oil, or performing a transmission overhaul to replace the clutches.
	انزلاق التروس	انخفاض مستوى الزيت أو تآكل كلتشات الاحتكاك.	استكمال الزيت، أو توضيب الناقل (Overhaul) لاستبدال الكلتشات.
2	Delayed transmission	Blocked filter or low hydraulic pump pressure.	Change the oil and filter, and perform a hydraulic line pressure test.
	تأخر النقل	انسداد الفلتر أو ضعف ضغط المضخة الهيدروليكية.	تبدال الزيت والفلتر، وفحص ضغط الخط الهيدروليكي (Line Pressure Test).
٣	Noise in neutral position	Wearing of input shaft bearings.	Disassemble the conveyor and replace the damaged bearings.
	ضوضاء في وضع الحياد	تآكل محامل عمود الإدخال (Input Shaft Bearings).	فك الناقل واستبدال المحامل التالفة.
٤	Rough/Smooth Transmission	Faulty solenoids or speed sensor.	Inspect the solenoids with an OBD-II scanner and replace any faulty ones.
	النقل الخشن / روعة النقل	خلل في صمامات التحكم الكهربائية (Solenoids) أو حساس السرعة.	فحص الصمامات بجهاز الفحص (OBD-II) واستبدال التالف منها.

Importance of regular transmission fluid checks and replacements

Transmission fluid (ATF/CVTF) is the lifeblood of this system. It not only lubricates the transmission but also performs the following functions:

1. **Transmitting hydraulic power:** to operate the pistons and clutches (in automatic transmissions).

2. **Cooling:** transferring the high heat generated by friction to the vehicle's radiator.
3. **Friction modification:** ensuring smooth, slip-free shifting.

Example calculation: Calculating the heat generated in an automatic transmission and its effect on the fluid.

Example 7.1: A vehicle traveling uphill, whose engine produces an input power to the gearbox of $P_{in} = 100 \text{ kW}$. If the overall transmission efficiency (Mechanical & Hydraulic Efficiency) of the transmission under these conditions is $\eta = 88\%$. The specific heat capacity of the transmission fluid is $C_p = 2.0 \text{ kJ/kg} \cdot ^\circ\text{C}$, and the oil flow rate to the cooler is $\dot{m} = 0.5 \text{ kg/s}$.

1. Calculate the power loss as heat P_{lost} .
2. Calculate the temperature rise of the fluid (ΔT) before it enters the cooler if all the lost heat is absorbed by the oil.

Solution

1. Calculating power loss (heat and potential for corrosion):
The power lost in the carrier is almost entirely converted into heat energy absorbed by the oil:

$$P_{lost} = P_{in}(1 - \eta)$$

$$P_{lost} = 100 * (1 - 0.88) = 12 \text{ kW} = 12 \text{ kJ/s}$$

That is, 12 kJ of thermal energy is generated in the carrier every second.

2. Calculating the rise in liquid temperature (ΔT):

باستخدام معادلة التبادل الحراري:

$$Q = \dot{m} * C_p * \Delta T$$

$$Q = P_{lost}$$

$$12 \frac{\text{kJ}}{\text{s}} = 0.5 \frac{\text{kg}}{\text{s}} * 2.0 \frac{\text{kJ}}{\text{kg} \cdot ^\circ\text{C}} * \Delta T$$

$$\Delta T = \frac{12}{0.5 * 2.0} \rightarrow \Delta T = 12 ^\circ\text{C}$$

" Modern and future automotive transmission systems technology"

"The radical shift from internal combustion engines (ICE) to electric drive systems has completely redefined transmission engineering. The goal is no longer simply to change gear ratios to suit the engine torque curve, but rather to maximize power flow efficiency and achieve optimal electromechanical integration."

First axis: Electric Vehicles and Their Powertrains (EV Powertrains)

In pure electric vehicles (BEVs), due to the electric motor's ability to deliver maximum torque from a standstill, the powertrain differs significantly from that of conventional cars:

- ✚ **Single-Speed Gearbox:** This is currently the most common type. It utilizes a fixed-ratio gearbox, typically ranging from 1:7 to 1:10, to reduce high engine speeds (sometimes reaching 16,000 RPM) and increase torque delivery to the wheels.
- ✚ **Two-Speed EV Transmissions:** These are gradually being adopted by manufacturers in sports cars and electric trucks. The first gear provides tremendous acceleration from a standstill, while the second gear reduces engine speed at high speeds on highways, thus improving battery efficiency and preventing engine overheating.

The second axis: Future trends in powertrain technology

The world is rapidly moving towards eliminating traditional mechanical complexities and replacing them with intelligent systems:

✚ **In-wheel/Hub Motors:**

Completely eliminating the gearbox and axles. The electric motor and a very compact transmission system are integrated within the wheel frame itself. This enables independent torque vectoring for each wheel and increases the efficiency of the vehicle's interior space.

✚ **Dedicated Hybrid Transmissions (DHT):**

For hybrid vehicles, transmissions are designed that mechanically and electrically integrate the combustion engine and electric motors into a single, compact unit that intelligently manages the flow of power using both mechanical and electrical components, eliminating the need for a traditional clutch.

The shift towards high voltage and advanced semiconductors:

Using silicon carbide (SiC)-based power inverters that can withstand voltages up to 800 volts, reducing heat loss in the transmission system and speeding up charging processes.

Third Axis: Case Studies of Advanced Transmission Systems

Case 1: The Transmission System of the Porsche Taycan

 **Innovation:** The first production electric vehicle to adopt a two-speed gearbox mounted on the rear axle.

 **Mechanism of Operation:** The first gear with a very high reduction ratio provides the vehicle with rapid acceleration from a standstill. Upon reaching a certain speed, a transmission based on an electromagnetic clutch smoothly shifts to the longer second gear to improve fuel efficiency on highways.

Case 2: The Drivetrain of the Toyota Hybrid Synergy Drive (HSD)

 **Innovation:** The use of a planetary gear set as a power split device, eliminating the need for traditional sequential gears.

 **Mechanism of Operation:** The system connects a gasoline engine, an electric generator (MG1), and an electric drive motor (MG2). Through electronic control of the generator speed, the system can continuously and infinitely change the engine-to-wheel ratio (e-CVT), ensuring the combustion engine always operates at its highest thermodynamic efficiency.

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