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Improving a Clutch Performance using a Friction Disc Manufactured from Composite Material

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By

Esraa Kadhim Ibrahim Mahdi

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Supervised by

Prof.Dr	**Assist.Prof.Dr**
Lutfi Yousuf Zedan	**Ekhlas Edan Kader**

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بسم الله الرحمن الرحيم

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صدق الله العظيم

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LIST OF ABBREVIATIONS

Symbol	Term
Nov.	Novolak Resin
HMTA	Hexamethelne Tetramine
Com,	Composite Material.
S_1	Sample One
S_2	Sample Two
S_3	Sample Three
S_4	Sample Four
Mgo	Magnesium Oxide
Zn$(C_{18}H_{35}O_2)$2	Stearate Zinc
(Fe_2O_3)	Ferrous Oxide Filings
(Al_2O_3)	Alumina Oxide
(Sb_2S_3)	Antimony Trisulfide
PMC	Polymer Matrix Composite

LIST OF SYMBOLS

Symbol	Term	Units
ρ	Density	g/cm^3
ε	Strain	
ζ	Damping ratio	
µ	coefficient of friction	
σ_c	compressive strength	(N/m^2)
E	Modulus of elasticity	Gpa
K	Thermal conductivity	$W/m.$℃
i	Electric current	A
v	Voltage	V
r	Radius	m
e	Heat loss per unit time (sec) through cross section area (m^2)	
W.R	Wear rate	g/cm
ΔW	Weight loss	g
S.D	Sliding distance	cm
v	Sliding velocity	$^{cm}/_{sec}$
N	Angular velocity	(r.p.m)
Wd	Damping frequency	$^{rad}/_{sec}$
r_o	External or outside radius of friction lining on clutch plate	m
r_i	Internal or inside radius of friction lining on clutch plate	m
p	intensity of pressure	KN/M^2
W	Total axial load or axial thrust with which the friction surfaces are held together.	N

T	torque transmitted	N-m
F	Force used or given	N
A	Sample section area	(mm^2)

Chapter One
Introduction

1-1 General Review

A clutch is a mechanical device which provides driving force to another mechanism, typically by connecting the driven mechanism to the driving mechanism. Its opposite component is a brake, which inhibits motion. Clutches are useful in devices that have two rotating shafts. In these devices, one shaft is typically attached to a motor or other power unit (the driving member), and the other shaft (the driven member) provides output power for work to be done [1].

1-2 Function of the Clutch

The main primary function of the clutch is to transmit the torque from engine to driven shaft and engage and disengage the transmission system. The secondary function is related to vibration and damping. When the friction clutch begins to engage, slipping occurs between the contact surfaces such as pressure plate, friction plate and flywheel and due to this slipping, heat energy will be generated on friction plate surfaces. A popularly known application of clutch is in automotive vehicles where it is used to connect the engine and the gear box. Clutches are also used extensively in production machinery of all types. In friction clutches, the connection of the engine shaft to the gear box shaft is affected by friction between two or more rotating concentric surfaces. The surfaces can be pressed firmly against one another when engaged and the clutch tends to rotate as a single unit [1].

1-3 Types of Clutches

The type of clutch used on an automotive depends upon several factors, including the nature of the service in which the clutch will operate, the maximum engine torque developed, and the type of transmission [2]. Automotive clutch is divided into several types [2] and [3]:

1-3-1 Rigid Body clutch

It is divided into two types:

a) Positive engagement type
b) Free wheel type

1-3-2 Friction clutch

The work of these clutches depends on the friction property of moving the movement from one rotated part to another fixed part to be the same rotational speed, it is the most used in vehicle transmissions, To transfer the power from the engine to the gear box, the work of this clutch is required to be centered on a one line with the engine and other transmissions [2].

There are several types of friction clutch[2]and [3]:

1-Single plate friction clutch

Figure (1-1) shows a single plate friction clutch used in regular passenger cars , the clutch usually consists of the following parts :

i.Pressure plate

It is called by this name because it works to compress the friction disc and runs directly with the engine.

ii.Friction disc

It is divided into:-

1-Wet Type

2- Dry Type

It is the basis of clutch work because it is the disc that transmits the power from the motor by friction. The friction lining is installed on both sides of the plates by rivet,so that there is a friction surface opposite the fly wheel and the other surface opposite pressure disc. There is a number of torsion springs installed on the friction disc,It minimizes the Torsion strain generated at the beginning of power transfer.

iii.Clutch Shaft

This shaft is intertwined with a friction disc and intertwined with a gearbox from the other side.The shaft transfers the power of the fly wheel through the friction disc to the gear box.

iv.Springs

The torsion springs are the main element in the applicability of the pressure disc to the friction disc and preventing the slipping.

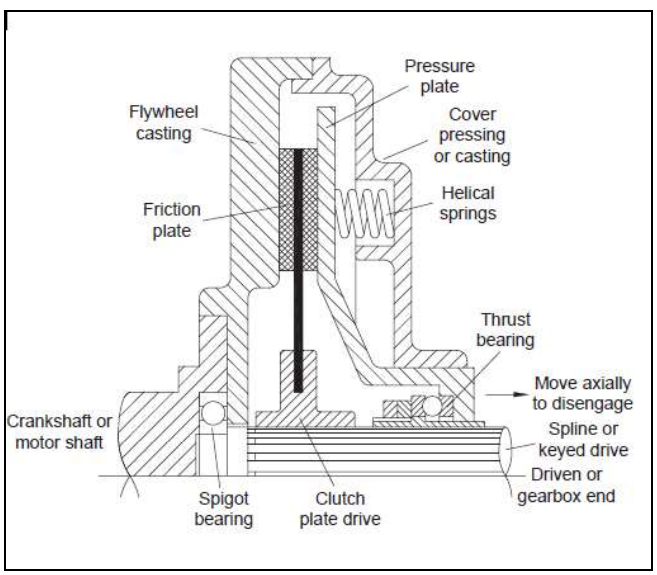

Figure 1.1 Single plate friction clutch [2].

2-Multi Disc Friction Clutch

1.3.3 Cone Friction Clutch

1.3.4 Center Fugal Friction

1.3.5 Hydraulic Clutch

1.3.6 Magnetic Clutch

1.4 Composite Materials

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties [4].Composite materials can be classified into three types depending on the type of matrix materials. Used as: polymer matrix composite (PMC), ceramic matrix composite (CMC), and metal matrix composite (MMC). Each type of composite material is appropriate for diverse applications. The most commonly used composite material is polymer matrix composite because their strength and stiffness is lower than ceramics and metal, and these defects can be solved by reinforcing other materials with polymers [5].

1-5 Matrix

Binding the fibers together in an orderly array and protecting them from the environment is the role of the matrix. The matrix transfers loads to the fibers and is critical in compression loading in preventing premature failure due to fiber micro buckling. The matrix also provides the composite with toughness, damage tolerance, and impact and abrasion resistance. The properties of the matrix also determine the maximum usage temperature, resistance to moisture and fluids, and thermal and oxidative stability [4].

1-6 Polymers

Polymers are large molecules made up of a large number of (generally structural units) linked together by chemical bonds forming long chains. The elements of these strings (Repeated unite) are called monomers. These monomers combine to form large multi-particle forms, either Linear, Branched, or Cross-Link [5]. The average number of repeated units in the large series is called the degree of polymerization. Polymers with high polymerization are known as polymers with a high molecular weight. Polymers with low polymerization are known as oligomer polymers. The higher the polymerization of a polymer, the greater the molecular weight [6].

1-7 Polymers types

Polymers can be classified according to their structural characteristics and their practical uses into two major groups:

1. Thermoplastic polymers

They are polymers having hard textures, melting by heat to became like a paste but when the temperature of these polymers approaches the degree of glass transition, it became plastic when their plasticity increases it converted to fused viscous and when the molten temperature is reduced, it returns to its solid hard state [7].Because of the polymer's longitudinal extension only, the contiguous chains are associated with natural secondary attraction forces (not covalent). When heating these polymers, thermal energy overcomes the weak natural forces of attraction. As a result of the loss of the force of attraction slip occurs of polymer’s chains on each other and thus cause smelting and liquefied of these polymers longitudinally. Examples of this type Polyethylene, nylon and polystyrene [8].

2. Thermosetting polymers

These materials are in contrast to heat-tolerant polymers because they are not softened by heating. But heat help them to take their final form consistently after casting in special molds. They became hardness is caused by heat due to the chemical changes that occur during the heating process. Chains make polymer tangle converting to non-fusion polymers and not dissolved in common solvents causing poor thermal conductivity and electricity. They are therefore used as insulating materials for heat and electricity [8].

The chains are bounded together by strong chemical bonds that not easily broken. These materials cannot be recycled when exposed to a certain temperature. When the temperature increases, they coaled and break down thermally as they are not susceptible to heat under the decomposition temperature. These polymers are characterized by low density, strength and high stiffness. Example of these type are Phenol resins, formaldehyde, epoxy and polyester ester unsaturated [9].

1-8 Phenol Formaldehyde Resins

This type of polymer composed of two main materials: phenol and formaldehyde. Phenol is a colorless solid compound but it is colored in pink then brown due to oxidation in air. It smells pungent, melts at 42.3 ° C and boils at 182 ° C. The most prominent characteristics it is corrosive behavior so when dealing with it wear protective clothing for humans should be used because exposure to high concentration cause serious burns [10].

Phenol is widely used in the manufacture of materials for plastics, including drinking water bottles and also in the clothing industry, and installation of nylon. It has medical uses, in the manufacture of disinfectants, lotions, ointments, topical anesthetics and the pharmaceutical industry [11].

1-9 Formaldehyde

Formaldehyde is a chemically rapid combustion organic compound (CH_2O), a colorless gas that can be dissolved in water in large quantities. The water solution, which contains a concentration of 40% formaldehyde, is called formalin. The latter is used as a preservative for tissues and in embalming, as the boiling point reaches 21℃.It is also used in veterinary and dental medicine as well as in the production of chemicals and polymers and is often used in the manufacture of paints and explosives [12]. In general, polyphenol formaldehyde prepared in two ways and produced two types of polymers namely resole and novolac [11].

1-10 Resole

This type is produced by using a base helper with more formaldehyde relative to phenol. Initially, Oligomer is called resol and then turns into a synaptic polymer when treated with heat [9]and [10].

1-10-1 Novolac

This type of polymers produce by combines formaldehyde (a 37% water solution) with phenol with an acidic helper (sulfuric, phosphoric or oxalic acid).It is heated to boiling under reflux until it reaches the required level, then the reaction mixture is equalized and the water is distilled (in its final stages under discharge) to a temperature of 160 ° C [9][11].

The resin is used in many industrial processes, including the production of utensils that are characterized by heat resistance and insulation. It is also used in the manufacture of adhesives, when using the appropriate solvent. as well as in space applications as it turns in the high temperatures resulting from friction to carbon to be a layer of charred insulating and protective for the introduction of space shuttle and other applications [8] [11].

1-11 Hexamethyleneteramine

Novolac resins are chemically converted from heat-resistant polymers to non-heat-resistant polymers, because these resins do not have a hydroxyl group that is sufficient for scientific purposes. It cannot be converted into a high molecular weight molecular polymer by heating alone. This is one of the essential differences between resol and novolac. Thus, novolac is hardened by an additional amount of formaldehyde by oxidizing chemical agents that increase cross-bonding. The most commonly used material for hardening is HMTA. A solid material with a high melting point (300 ℃). The reactions between novolac with HMTA is accompanied it decompose ammonia gas 95% [13].The reactions of novolac with HMTA occur at relatively high temperatures ranging from 100 to 150 ° C under certain pressure to reduce the porosity generated by the Volatile Components that accompanied with decomposition of HMTA.

1-12 Reinforcements

The basic purpose of adding reinforcing materials is to reduce the cost and improve the mechanical and physical properties of the matrix material. It works to increase the strength of the matrix material that should be strength and stiffener compared to the matrix material. Reinforcements improve resistant to wear and improve the properties of electrical and thermal conductivity depending on the type of material used and change the mechanism of failure in a positive direction. The high toughness requirements include little or no ductility, which makes the materials relatively brittle. The reinforcement materials may be ceramic, metal or polymers, characterized by high stiffness and resistance having different forms: fiber, particles, peel, sheets or fillers [14]and [12].

1-12-1 Fibers

Fibers are defined as regular pattern structures have distinct properties that reinforce the matrix in the composite material. Fibers are the mainstay, as they bear the bulk of the load on the composite material. In ceramic-matrix material, the matrix is brittle and fiber is the barrier against the growth of defects. They increase the stiffness of the material. The properties of the composite fiber-reinforced material are closely related to fiber properties (fiber diameter, volumetric fracture, fiber length, fiber composition). Fiber in general can be classify it to: [15].

1-12-1-1 Manmade Fibers

Manmade Fibers are fibers that are not naturally present in nature and are made artificially by man. Manmade fibers have high strength, strong when wet and low moisture absorption characteristics. Examples of manmade fibers are viscose rayon, acetate rayon, nylon, polyester etc. Depending on raw material choosed for making fibers they may classified into: cellulosic fibers, protein fibers and synthetic fibers [16].

1. **Kevlar**

Aramid fibers are an aromatic polyamide or aramid fiber introduced in early 1970s by DuPont. These aromatic polyamides are part of the nylon family. It was the first organic fiber with sufficient tensile strength and modulus used in advanced composites. Originally developed as a replacement for steel in radial tires [16]. A major advantage of aramid fibers is their ability to absorb large amounts of energy during fracturing, due to from their high strain-to-failure values, their ability to undergo plastic deformation in compression, and their ability to defibrillate during tensile fracture. Kevlar fibrillar structure and compressive behavior contribute to composites that are less notch sensitive and that fail in a ductile, nonbrittle, or noncatastrophic manner, in contrast to glass and carbon [15]. The three most prevalent aramid fibers are Kevlar 29, Kevlar 49, and Kevlar 149. The Kevlar has several properties such as: high modulus of rigidity, high strength to weight ratio, low electrical conductivity, high toughness, and low coefficient of thermal expansion.Tensile strength of Kevlar fiber 49 ranges from about 2.6 to 4.1 GPa. Tensile Elongation is 2.8%, Tensile Modulus is 131GPa, and Density $1.44 g/M^3$[17].

1-12-2 Antimony Trisulfide

The manufacture of antimony trioxide (ATO) involves a sublimation reaction of antimony metal with oxygen that results in a cubic crystalline lattice formation. Antimony Trioxide is a white crystalline powder of a ceramic character with very low solubility in water .The major use of ATO is as a flame retardant synergist in plastics. Polymerisat ion catalyst used in Polyethylene terephthalate resin manufacture, as a frictional additive in automotive clutch linings [18]. Physical and chemical properties of antimony trioxide shown in appendix A table [A-1].

1-12-3 Stearate zinc (Zn (C18H35O2)2)

Zinc stearate powder is an effective internal lubricant, it is the metallic carboxylate of choice in most polyolefin processing applications. Due to its functionality and low moisture content does not adversely hydrolyze phosphates or antioxidants. Zinc stearate is an extremely heat stable product [19]. Physical and chemical properties of Zinc stearate shown in appendix A table [A-2].

1-12-4 Magnesium Oxide (Mgo)

White powder, known as light magnesium oxide. 5 g of magnesium oxide occupy a volume of 40 to 50 ml, Magnesium oxide melting at (2800 ° C) is therefore used in thermal materials and insulators. Having low expansion and resistance to cracking because magnesium oxide has a crystalline cubic structure [20]. Physical and chemical properties of Mgo shown in appendix A table [A-3].

1-12-5 Aluminum oxide (AL_2O_3)

The commonly-used AL_2O_3produced through the Bayer process starting from bauxite.In the Bayer process, crushed bauxite is treated with caustic aluminate solution containing soda.The dissolution reaction is generally carried out under pressure at temperatures ranging from 140 to 280°C.The caustic solution reacts with the aluminum hydroxide so that the impurities can be separated by sedimentation and filtration. After precipitation of the hydroxide, (AL_2O_3)powders can be obtained through heat treatment at their transition temperatures [21]. Physical and chemical properties of (AL_2O_3)are in appendix A table [A-4].

1-12-6 Graphite

Graphite is an allotropic form of the element carbon consisting of layers of "hexagonally" coordinated carbon atoms in a planar condensed ring system (graphein layers, these planes also called basal plane). The atoms within the rings are bonded covalntly, while the layers are loosely bonded together by Vann der Walls forces. The remarkable combination of properties is because of its crystal structure. An example is the ability of graphite to solid film lubricant resulted from the two contracting chemical bonds. Actually, these weak Vann der Walls forces govern the bonding between individual layers permits, the layers to slide over one another making it an ideal lubricant. typical properties of graphite shown in appendix A table [A-5][22].

1-12-7 Bentonite

Bentonite is consisting of smectite dominated by montmorillonite. Among the smectite group. Montmorillonite is the most important commercially. It is a material derived from the alteration, over geological time periods, of glassy material emitted from volcanoes, or from the alteration of silica bearing rocks. Bentonite can have a variety of accessory minerals in addition to its constituent mineral Montomorillonite.Bentonite has properties which gives it a range of uses, such as: bonding material in the preparation of molding for the production of high quality castings,as filler in pharmaceuticals, as to remove the impurities in solvents and to soften the fabrics [23].

1-13 Aims of the Study

1. The main objective of this study is selecting the best composite materials.
2. A study was try to replace the commercial clutch plate that used in vehicle by novolac strengthening the novolac with fillers and fibers, and friction improvement to be used in Hyundai Elantra system as high quality friction linings to ensure optimal performance at high temperatures and for a long time.
3. It also aims at study effect of materials used (novolac and reinforcement, kevlar fiber49) as damping material to reduce vibrations.

4. This study is keen to know the maximum resistance of samples to compressive stresses, hardness, and to study their thermal conductivity to determine the efficiency of these materials to dissipate heat when exposed to wear during operation.

1-14 Layout of this Thesis

The study is divided into six chapters:

1. Chapter one includes general review, function of the clutch, matrix and reinforcements material that used in thesis, types of clutches, and aims of the study.
2. Chapter two includes introduction, and clarified development of disk clutch in vehicles by showed the literature review including same journals, same articles and same publications that related to the thesis subject.
3. Chapter three includes the theoretical framework considering rule of mixture theory, theory of plate clutch, and clarified mechanical properties by showed the tests.
4. Chapter four includes the experimental framework by giving details of materials used, composite manufacturing procedure and the applied tests.
5. Chapter five includes the results and discussion of the experimental work of the hybrid composite samples.
6. Chapter six includes the conclusions, recommendation and suggestions for future works.