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USING THE SCRAP TIRES TO PRODUCE A FLEXIBLE COUPLER

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ABSTRACT

The scrap tires considered a problematic source of waste, the old rubber tires causes a big environmental problem that is need much money and effort to disposes it safely. In Iraq there are more than two million used tires disposed to the environment annually. one of the tire's recycling methods is the use of tire layers to produce a new rubber parts used in the engineering and industrial purposes as the bridges and machines dampers, this trend of recycling doesn't take a sufficient care comparing with the other uses.

There are a lot of studies conducted in these field, these studies suggests many methods to manage the huge number of scrap tires, the current paper aims to use the old rubber tires in engineering purposes (especially as a coupler joins the motor or engines with the other equipment as electric dynamo or pumps), the study focusing on the mechanical properties of a strip from a used tires and comparing with one prepared in the lab., and suggesting a new method to use as an engineering parts (for example the coupler lays between the IC engine and the dynamo of an electric generator).

One of the results obtained from the experiments, there is no significant difference between the mechanical properties of the old and the new strip, (in the tensile test, the breaking force of the -Lab. tensile specimen- is 137 N whereas the specimen of old tire have a breaking force 113.27 N, but they are same in the elongation). A computational example is suggested to estimate the dimensions of a flexible coupler use an old tire pieces

KEY WORDS: tire recycling, rubber couplers, rubber properties.

1. LIST OF ABBREVIATIONS

Young's modulus at longitudinal axis, (Gpa)	E_1
Young's modulus at transverse axis, (Gpa)	E_2
Poisson's ratio at 1-2 plane	v1-2
Shear modulus at 1-2 plane, (Gpa	G1-2
Tensile strength at longitudinal axis, (Mpa)	σ_1
Fiber diameter, (m)	D
Modulus of elasticity for fibers, (Gpa)	E_f
Modulus of elasticity for rubber, (Gpa)	E_r
Fiber volume percentage	V_f
Rubber volume percentage	V_r
Poisson's ratio for fibers	ν_f
Poisson's ratio for rubber	ν_r
Fiber shear modulus, (Gpa)	G_f
Rubber shear modulus, (Gpa)	G_r
Number of ends in unit length,(m)	e
Composed layer thickness,(m	t
Factor of safety	f
Shear stress for the strip, (Mpa)	τ
Torque applied on the coupler, (N.m)	T
Number of strips used in the coupler	n, n'
Strip cross sectional area, (m^2)	A_L

2. INTRODUCTION

There are now nearly 900 million vehicles of various types in the world , and if we assume that each medium vehicle has six tires, there are more than five billion tires operates in service, and if the tire lifespan is 50, 000 km, so this number will be out of service after a period not exceeding three years, (for example, In the USA, an estimated 300 million tires are disposed of annually) whereas there are two billion tire accumulated (Rafat and Tarun, 2004). The question now is where this goes the huge number of tires which will be repeated annually. These tires are estimated at 38.4 million tons of used tires annually renounces to nature and be disposed of either by burning or by burial, but in fact that Fortune did not notice her (Tony, 2010).

Recently states started paying attention to the real value of used tires and began composing the nucleus for tire recycling industry. In recent years much research was conducted to determine the extent of use of used tires, and the main trends in this area are as follows:-

1. Use of the complete tire, either renewing it or use it in a function but not the function that made for, after the end of the life.
2. Use the tires parts (components, plies, etc.).
3. Use the tires as a source of energy production.

Current research is a modest contribution in this area where we suggest the use of scrap tires in mechanical parts industry such as rubber couplers.

2.1. Tire components

The pneumatic tire considered as a rubber container with layers of textile fibers arranged crossly or radially and filled with compressed air these layers are surrounded by a layer of metallic fabric covering with a layer of rubber molded in a form fits to its function.

Tires varies in the number of layers that make up, passenger car tires contain 2-4 layers, while the large transport vehicles composed of 14 layers, while the heavy off- truck vehicle tires composed of 32 layers, and the tread pattern varies depending on the nature of tire function .

2.2. Tire plies

1. Layer in contact with the ground (tread).
2. Internal fascia layer (breaker bandage).
3. Core layers (ply topping).
4. Metal fiber reinforced core layers (steel cord breaker topping).

5. Side wall Layers (wall side).
6. Heel coating layers (bead wire coating).
7. Heel padding (bead apex).
8. Internal lining layer (inner liner) (Lindemuth, 2006).

All the above parts should be integrated with each other in a good manner to generate a chemically stable construction; the better adhesion between these layers will produce tires with better performing (Baker, 2003). The basic materials that the tire composed are: rubber, steel wire, textile layers consisting usually of artificial fibers (rayon, nylon, or cotton), the textile layers coated with rubber glue; Table 1 shows the proportions of the typical components for the tire construction (Ann and Russ, 2006).

Table 1. The composition of a tire (Lindemuth, 2006).

Ingredient	Passenger Car	Lorry Tyre	OTR Tyre
Rubber/Elastomers	∀47%	∀45%	∀47%
Carbon Black	∀21.5%	∀22%	∀22%
Metal	∀16.5%	∀25%	∀12%
Textile	∀5.5%	--	∀10%
Zinc Oxide	∀1%	∀2%	∀2%
Sulphur	∀1%	∀1%	∀1%
Additives	∀7.5%	∀5%	∀6%
Carbon-based materials, total	∀74%	∀67%	∀76%

After expiry, tire recycling process can be divided into two main parts:

Part one: nondestructive

That is the use of the tire without processing, such as shredding or burning ..etc. and can summarize the uses of the whole tire as following (Waste Organization, 2007):

1. Using the whole tire after re grooving.
2. Remolding the tread ply.

3. Using the whole tire in the seaports.
4. Using tire as bumpers in circuit racing cars and bikes.

Part two: destructive

This type is more complication than the first one, because it needs other chemical and mechanical processes, taking place on the tire in order to take benefit of it after the change, and there are a large number uses of this kind, summarizes with the following (Ann and Russ, 2006):

1. Tire grinding: In this process, producing rubbers grains in different sizes by sharpening the tires. It is used in flooring pitches, under brushes as a barrier to moisture, as well as in covering streets after mixing with asphalt.
2. Grind of tire slices with excessive cooling (cryogenic process)
3. In this process, tire is shredded into slices, and then cooled to the temperature of (- 80) degrees then grinds with a special hammer to separates the components, The resulting granules used in playgrounds and floors also in covering streets as well.
4. Re vulcanization (de vulcanization) : in this process Vulcanized rubber treats chemically and thermally to obtain non- vulcanized rubber reused again this method called (reclaimation)
5. Microwave technology (AMAT-Advance Molecular Agitation Technology): in this method dismantling the tire to its original components by exposing it to the microwave.
6. Ply separation: Where each ply is separated from the other tire plies by mechanical methods and is used in many areas such as: rubber washers industry, rubber belts, containers used in animal feed, the cushions to reduce vibrations under bridges…etc.
7. Energy production (energy recovery) tire contains 60% of hydrocarbon which stores energy this energy can be generated in the following ways:

- Method of analysis to the basic components (Pyrolysis process):

  It is a process of thermochemical decomposition to break down the bonds between the components of the tire material under a height temperature (500-900) degrees, in the absence of oxygen (or any halogen) to generate a mixture of flammable gases, oil, and solid materials.

- Method of generate energy directly from burning tires (tire-derived fuel):

It is a common way in reusing tires as a direct source for power generation at cement plants rather than coal or solids, as well as in electric power generation. Energy generated here 125% more than that of coal and 300% of solids (Paul, 1999).

3. MECHANICAL PROPERTIES OF RECYCLED TIRES PARTS:

Mechanical properties vary depending on the location of the sample taken from the tire, for example, the tread region that contains the core layers as well as the- under tread- plies, are highly resistant to tensile strength while the side wall area more flexible and more resistant to fatigue, there are many studies have dealt with the mechanical properties of recycled tires (scrap tires) (Campbell, 2010).

If we consider any part of the tire, a composite material of rubber and fibers, then we can use the equations and laws which are govern the composites material resistant, (Fig. 1 fiber- rubber composite).

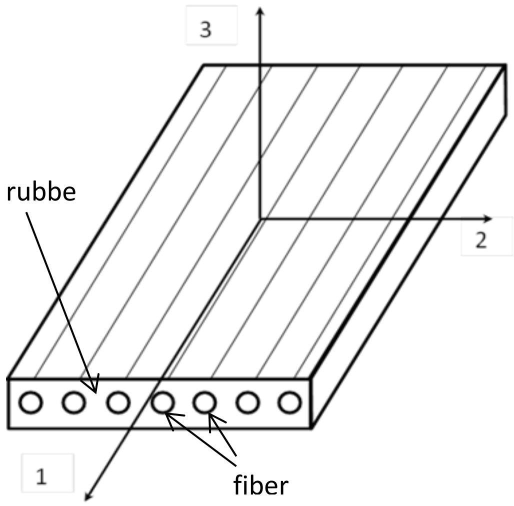

Fig. 1 Fiber-rubber composite (Campbell, 2010).

To calculate the independent constants of elasticity, to single layer composite material, we can use the equation called the mixture rule:

$$E_1 = E_f V_f + E_r V_r \quad (1)$$

$$\sigma_1 = \sigma_f V_f + \sigma_r V_r \quad (2)$$

While:

$$V_f + V_r = 1 \quad (3)$$

$$V_f = \frac{\pi D^2 e}{4t} \quad (4)$$

Considering the length and width of the strip are unity.

Many composite materials which consist of rubber and fibers, the fiber modulus of elasticity greater (100-1000) times the modulus of elasticity of rubber (Asaad, 2006), that can bring the equation (1) to be as follows:

$$E1 \approx E_f\, V_f \quad (5)$$

$$\sigma 1 \approx \sigma_f\, V_f \quad (6)$$

Poisson's ratio and shear modulus can be calculated by the

$$\nu_{1-2} = \nu_f V_f + \nu_r V_r \quad (7)$$

$$\frac{1}{G12} = \frac{V_f}{G_f} + \frac{V_r}{G_r} \quad (8)$$

Because of G_f » G_r then:

$$G_{12} = \frac{G_r}{V_r} \quad (9)$$

The modulus of elasticity in the transverse direction can be estimated from the equation:

$$\frac{1}{E2} = \frac{V_f}{E_f} + \frac{V_r}{E_r} \quad (10)$$

Also because of $E_f \gg E_r$

$$E2 = \frac{E_r}{V_r}$$

While these micromechanics equations are useful for a first estimation of lamina properties when no data are available, they generally do not yield sufficiently accurate values for design purposes.

For design purposes, basic lamina and laminate properties should be determined using actual mechanical property testing (Campbell, 2010).

Practical experiment was conducted on two samples, one taken from a used tire, and the other was prepared in the lab, with the same dimensions and ingredients and measured the breaking force to both samples using a tensile strength attachment and the result was: the breaking strength of the standard sample (N 137) a little bit greater than the breaking force of the sample from a used tire (113.27 N).

3.1. Tire coupler

The coupler uses tire to transmit the power between the driven, and the driving shafts for a lot of machines with medium capacity, in these types of coupler overcomes misalignment of shafts between 4° , and parallel misalignment within 3 mm, the coupler works as a floating end, as well as to reduces the shock loads which leads to high stresses reduces the machine life, that is requires the flexible element of the coupler to be solid enough to absorb such shocks, in this couplers, the tire makes loads smooth, both to driven and driving shafts (Baker, 2003).

Couplers consist of three basic parts as shown in (Fig. 2):

- The hub and the pressure plate. (Consists of cast iron or forged steel),

- Installation screws.

- Rubber tire (which is made of rubber supported by artificial fabrics), the hardness of rubber (IRH 70 ± 5^o), there are tire coupler works at a different values of power extend from 15 kW to 12500 kW, and different speeds ranging from 900-5500 rpm and dimensions vary depending on the power and speed required (Gitin and Prasad, 1995).

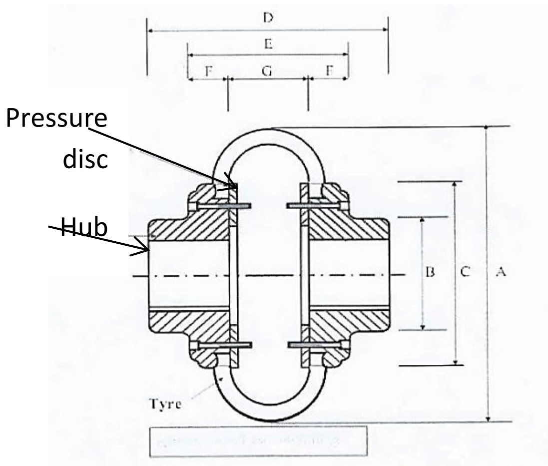

Fig. 2. Tire coupler (Baker, 2003).

4. THE SUGGESTED DESIGN:

The suggested coupler considers a flexible coupler, the flexible element consists of layers of used tire, it is different from the tire coupler where the flexible element is consist of a full tire of fiber reinforced rubber (nylon or rayon fibers), while the suggested flexible element consist of strips or cross from a layers of used tire, its dimensions depends upon the carried load, (Fig. 3), the strips or cross installed by a pressure discs or directly by Installation screws, to the flywheel of the engine and the flange of the generator

The thickness of the strips or the cross depends on the load carried (strip sectional area = width (w) x strip thickness (t)). And that’s where the thickness contains a finite number of two or more layers, then the Flexible element holds a dynamic, tensile and shear, forces depends on the number of layers used in the strip, while other dimensions for the coupler can be selected from the design tables as follows:

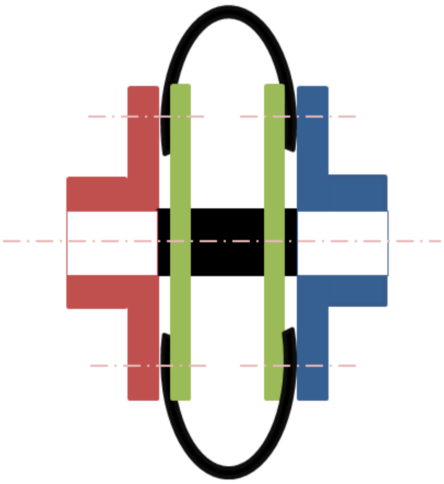

Fig. 3. Suggested flexible coupler.

4.1. practice:

A flexible coupler installed between internal combustion engine and electric generator motor the nominal power capacity 30 kW and speed 3000 rpm operational daily rate is 10 hours/day and operates four times per hour, and the temperature of 30 – 50 °C Nominal power =30 kW (Gitin and Prasad, 1995).

$$design\ power\ = nominal\ power\ \times f_1 \times f_2 \times f_3$$

f_1 = minimum factor of safety for types of duty.

f_2 = factor of safety for daily operation.

f_3 = factor of safety for frequency of start.

From tables:

$f_1 = 1$, $f_2 = 1.12$, $f_3 = 1.09$

Then:

$$design\ power\ = nominal\ power\ \times 1 \times 1.12 \times 1.09 = 36.624\ kw \approx 37\ kw$$

$$Power/speed\ ratio\ = P\ kw / rpm$$

$$= 0.0123308\ \ kw/rpm$$

$$= 1.23308\ kw / 100rpm$$

From tables:

The dimensions suitable for coupler have > 1 and < 2.1 are estimated as:

Torque =150 N.m

Mass speed = 3200 rpm

Boar In minimum rough = 30 mm

Boar in maximum rough = 55 mm

A =212 mm, B = 95 mm, C = 169 mm, D= 157 mm, E= 83 mm

F = 56 mm, G =45 mm

The dimensions (A, B, C, D, E, F, G) shown in Fig. 3.

When used coupler of used tire strips, shear stress for one single layer strip with cross- sectional area (A_L= 0.002 x 0.1) meters will be:

$$\tau = \frac{T}{0.5\ A \times A_L} = 7.07\text{x}10^6\ \text{N/m}^2$$ (A = the dimension in Fig. 2 (Gitin and Prasad, 1995))

From the experimental values, the shear stress for a layer of rubber-fabric composite materials is 3.82 x 10^6 N / m^2 **(**Campbell, 2010)**.**

Then the number of strips to be used in the coupler is:

$$n = \frac{\tau}{G} = 1.845 \approx 2$$

If we take a factor of safety f =2 then:

$$n' = f \times n_s = 4$$

This coupler is made up of four strips of one layer it can be replaced by two strips of two layers

5. DISCUSSION:

The comparison of the results from the laboratory sample with the sample of used tires (Fig. 4), shows that there is a difference in the breaking force, which is almost 17%, this difference is because of that the sample taken from used tires have been subjected to the tensile force during its lifetime, whereas the new artificial fibers used in the tire industry are meandered to absorb the initial tension during tire inflation, after a period of usage it becomes back straight, thus the tensile strength are imposed directly, and for this reason the breaking force of the used sample, less a small acceptable fraction than the New sample, versus the benefits obtained by the use of parts of used tires.

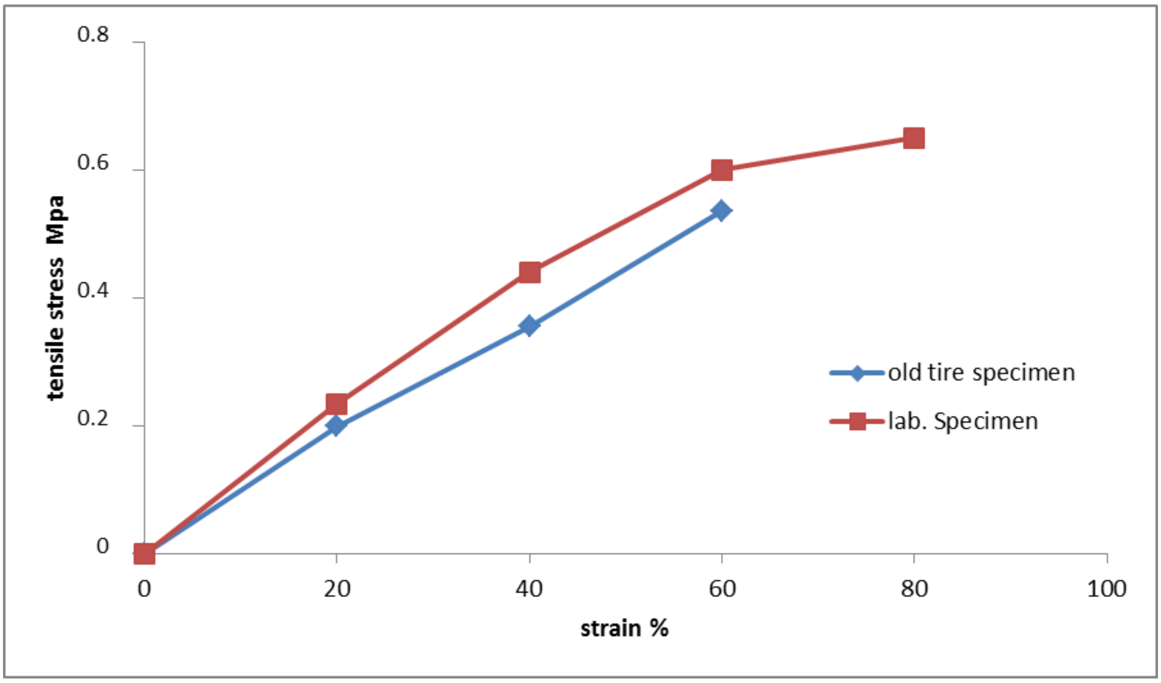

Fig. 4. Relation between stress and strain for old tire composite strep and lab. Specimen.

6. CONCLUSIONS:

Recently the using of used tires (tire recycling) takes a great interest by many States and organizations, using parts of used tires still constricted due to the tendency of so many producers to manufacture parts of new raw materials, it's shown through current research:

1. Mechanical properties have not changed substantially from what in the laboratory sample (control sample).
2. The breaking strength of the sample taken from a used tire (113.27 N), While the breaking strength of the sample prepared in the lab (137 N) (17.32%) greater than that of the past sample.
3. We can use strips of used tire to coupling the dynamo with the internal combustion engine in the generators of medium capacity (less than 30 kw) and a minimum of four separate strips or in the form of a cross.

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