Design of A Test Rig for Experimental Evaluation of Tyre Wear in Dry and Wet Test

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Abstract:- **Evaluation of tyre wear in dry and wet conditions shows the different wear rates at respective loads on tyre by employing abrasion behaviour. The purpose of work is to carry out wear rates of selected tyre specimen. There are lots of abrasive used but in our case we are evaluating the abrasion of tyre specimen by using sand. The tyre wear due to temperature analysis, coefficient of friction are conducted by various experiments which shows the results for analysing tyre wear. Test rig is designed to estimate the wear rates in abrasion of tyre specimen by applying lab prepared road samples. Wear rates are calculated by Archard's wear theory, whereas speed of tyre specimen is measured by using digital tachometer. Wear rates with respect to dry condition are more than the wet condition due to presence of water. This research is applicable for evaluating tyre wear in dry and wet condition in case of abrasion wear.**

Keywords- Tyre wear, abrasion behaviour, wear rates, lubrication

I. INTRODUCTION

Various tyre wear and tear types are related to the contact surface between the tyre and road. Whereas in case of lab abrasive tests of tyre specimen, the main objective is to evaluate the effects of abrasive employed at the respective loads and speeds. The conditions applied such as dry and wet on the specimen shows the results of wear rates. Wear and tear of tyre causes the burst of tyre, puncture, over inflated, under inflated, improper balancing, worm or damaged steering, hard cornering, improper alignment(Toe in and Toe out). So there is need of evaluation of tyre wear to obtain the actual working condition of tyre by calculating it's wear rates.

Sreeraj R.et.al [1] have studied the various types of tread patterns and conclude that the tread pattern is an arrangement of blocks, voids, channels, sips and grooves, which are designed in such a way to grip on tyre. Finite element analysis were carried out on the tread pattern for showing it's performance in rolling condition of tyre in steady state, which results in predicting there behaviour on road condition. So the optimum results of tyre wear and inflection pressure were obtained.

S.Wirojanuptump et al [2] have research on abrasion behaviour with rotating wheel type apparatus, which were examined with angular alumina and rounded silica as an abrasive. The experiment has been performed on the two different types of wheels namely, rubber wheel and steel wheel including experimental conditions. As per size of abrasive, the presence of wet conditions affects on wear, in such case two body abrasion may get favoured. Cutting enhanced and particle embedment takes place. Where after results, the steel wheel tends to produce more fragmentation of abrasive, perhaps in wet condition, the stress on the particle are lower. Water plays an important role in both conditions of wheels and affects on fragmentation of particle, motion of particle, which leads to effects on wear rates.

Kreider M.L. et al [3] have worked on the size of wear and tear of light motor vehicles such as cars, autorickshaws, etc. In this case, tyres are interacted with the pavement in road simulator. Conclusion of work shows that wear and tear are depend on the size of particles interacted on the tyre surface.

J.A.Hawk et al [4] have concluded that there are various inexpensive ways of obtaining the information on the wear rates of tyre and wear mechanism i.e. screening materials, laboratory abrasive. Wear tests are limited on the two body abrasion and three body abrasion. If the tests were rank on their performance in wear mechanism, then they are-1.dry-sand, rubber wheel, three body abrasion, low stress abrasion, 2.pin on drum, two body abrasion, high stress abrasion, 3.Jaw-crusher, high stress, gouging abrasion, 4.high speed impeller-tumbler impact abrasion. The results from the gouging abrasion and impact abrasion were described to highlight the wear mechanism.

W.J.DiM Steyn et al [5] have investigated on the wear and tear of the tyre on the road simulator. Size of wear and tear of the tyre depends on the construction of particles used in road pavement.

Bin Ma. Et al [6] have proposed the mathematical method to analyse the tyre marks for prediction of vehicle operating status. Mainly they focused on the vehicle dynamics. The kinematic sliding friction coefficient with the road effect is simplified in new model. Furthermore a theoretical model of tyre wear are combined with the road properties and vehicle dynamics. The vehicle road coupling alignment were studied and analysed to asses the wear quantity and conditions. Result shows that vehicle speed, braking force and road surface mainly leads to wear of tyre.

Manfred Kluppel et al [7] have studied on wear and abrasion of tyre which were strongly influenced by the tyre operation and testing. Tyre surface wear is related to the topology of the worn surface. Tyre design, severity, tyre tread material influenced the tyre wear.

Tyre wear analysed by Archard's wear theory and by including the software ABAQUS 6.14 for analysis purpose [1,2]. Several author have perform the laboratory tests on the abrasion behaviour of the tyre specimen and found different type of abrasion causes different wear and tear rates of tyre

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[2,4]. The road simulator which is made from asphalt concrete pavement i.e. mixture of sand, gravel, crushed stones and recycle concrete bound together with asphalt [3,5]. The paper aims to study the wear rates of the selected tyre specimen in environmental conditions such as dry and wet conditions. The another application of this research work is that wastage of tyre can be controlled by knowing that the tyre is actual wear or not. If not, then we can use that tyre to its end life on the local routes at low speeds. In this way, the wastage of tyre can be avoided.

II. DESIGN OF ELEMENTS

This section deals with the modelling, meshing and analysis of the test rig. The test rig is a group of different parts which includes input shaft, drum shaft, input shaft bearing, drum shaft bearing, load drum, container for abrasive, container for water, water flow pipe, flow pipe for abrasive, extend link for carrying test specimen, base, gear pinion arrangement, pulley, motor, belt, frame. Whereas base is made of cast iron for support purpose. On the other hand, as per requirement of assembly open belt drive is preferred with center angle 40^0 is chosen for readymade pulley. Extend link is for placing the contact of tyre specimen with load drum and other hand of that link, the load of desirable choice such as 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 kg is attached, to give load on the tyre in lab test. Motor of 1 HP is used for running the drum shaft. Digital tachometer is used for calculating the speed of tyre specimen. Bearings are selected to share the load on shaft equally. Selected bearing is 6004Zz from series 60. Whereas pinion and gear assembly, pipes, container were taken readymade as per requirement of test rig. The water container can store 2.5 liters of water at a time, whereas abrasive container can store 2 kg of sand at a time. Input shaft, drum shaft, load drum are the critical parts of assembly. So they need to modelled and analyzed.

2.1.Model and meshing of Elements

Modelling and meshing of the critical parts are done in this section.

2.1.1.Drum Shaft

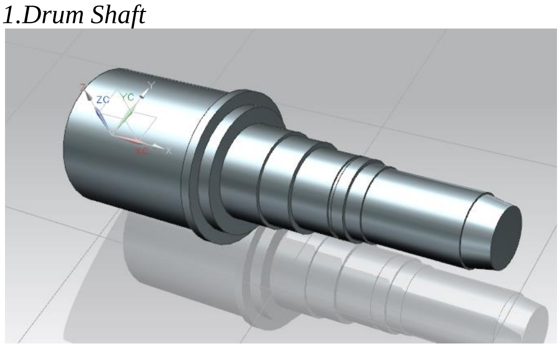

Fig.1.Model of drum shaft

Shafts are given specific names according to their applications, in this we are using the transmission shafts for transmitting power, motion and torque. This is made of the alloy steel as 40Cr4Mo2. As the alloy steel gives the higher strength, toughness and hardness as per the medium and high carbon steels. It also possess high resistance to corrosion. As the transmission shafts are subjected to the axial load, bending moment and torsional loading. Design is done on the diameter of the shaft and stresses involved in it.

$$T_{d}=\frac{\pi\times \sigma_{act} \times d^3}{16} \quad ....(1)$$

Selection Criteria for the shaft-The function of the Power transmission areas as follows: 1.To receive power from an a rotating shaft via a gear pair. 2.To transmit the power through machine elements that reduce the rotational speed to the desired value.

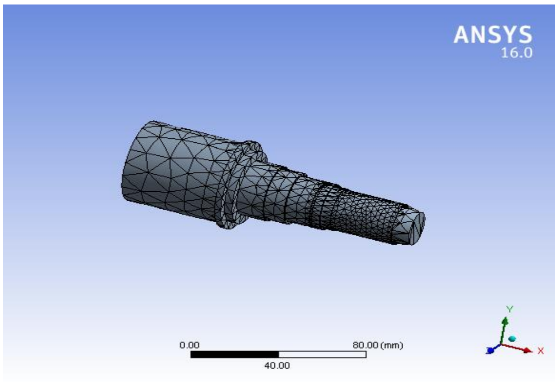

Fig.2.Mesh model of drum shaft

The CAD model is saved and imported in ANSYS software. Imported and meshed cleaned geometry is then meshed in tetrahedral element shows the 40mm maximum size of element. The critical part of element shows, the minimum size of element. Tetrahedral element always fit best complex geometry. Meshing of drum shaft is shown in fig.2. Meshing is shows the discretization of the material. Every part of drum shaft is meshed and shows the number of elements as 4533 and number of nodes as 7921.

In the same way, modelling and meshing of input shaft and drum shaft is done. But the number of nodes and elements are different. Summary of the parts are shown below.

Table.1.Detail summary of meshing of parts

Sr.No.	Part name	No. of nodes	No. of elements
1	Drum shaft	7921	4533
2	Input shaft	8222	4731
3	Load drum	9746	4639

2.2. Analysis

For analysis purpose the ANSYS software is preferred mostly. Hence we are using ANSYS software for analysis of drum shaft, input shaft and load drum.

2.2.1. Analysis of drum shaft

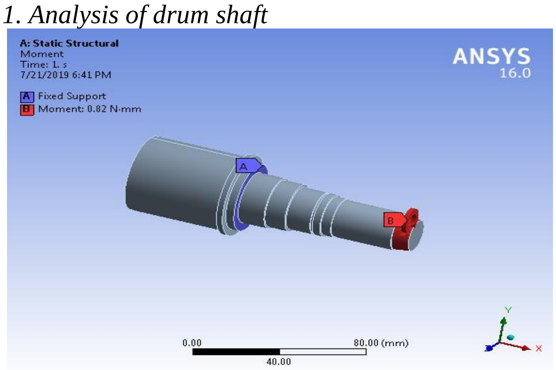

Fig.3.Boundary conditions applied to Drum shaft

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Different boundary conditions are applied at the place where gear is mounted and load drum rotates which shows formation of 0.82 N.mm of moment. As the motion transferred from the input shaft to the drum shaft gear, moment takes place where gear is suited.

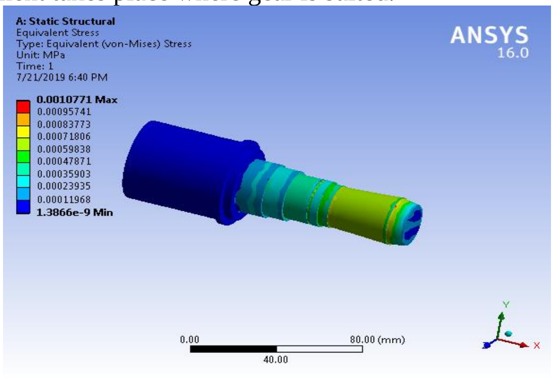

Fig.4.Static structural analysis of Drum shaft

The displacement, stresses, strains and forces in components are shown in static structural analysis, which are mainly caused due to load. The Von Misses stress should be lower than yield stress of the component, then the component is safe. The maximum Von mises stresses are 0.0010771 MPa whereas minimum Von mises stress are 1.3866e-9 MPa. Different colours shown in the Ansys format shows different values of Von mises stresses.

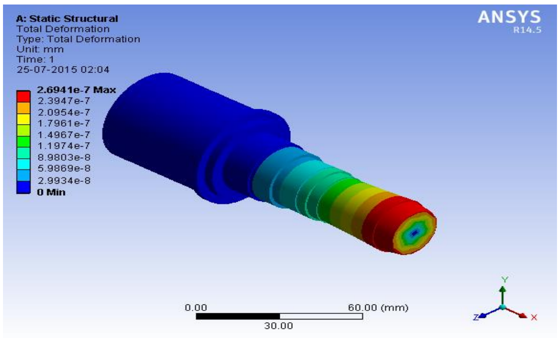

Fig.5.Total deformation of Drum shaft

Drum shaft is showing Total Deformation of 2.6941e-7 mm which is shown in the above fig.2.10. Where the gear is placed at the load drum, more deformation is shown. Because of gear rotates as per the rotation transferred from the input shaft. Drum shaft shows negligible deformation under the action of system of force, hence the drum shaft is safe.

2.2.2.Input Shaft

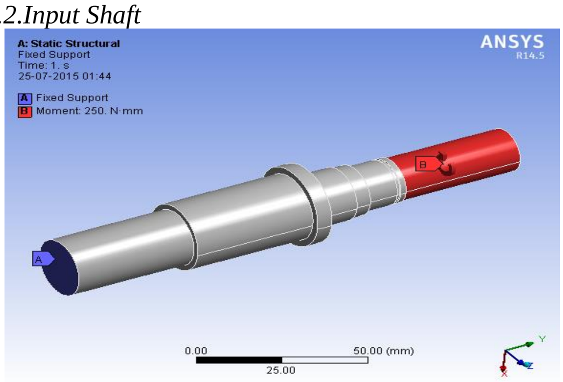

Fig.6.Boundary conditions applied to Input shaft

Boundary conditions are applied at the place where the pinion is mounted and at the end where pulley is suited. Through the pulley open belt drive is connected to the motor and motion goes on. 250 N.mm moment is given at the place where pinion movement takes place.

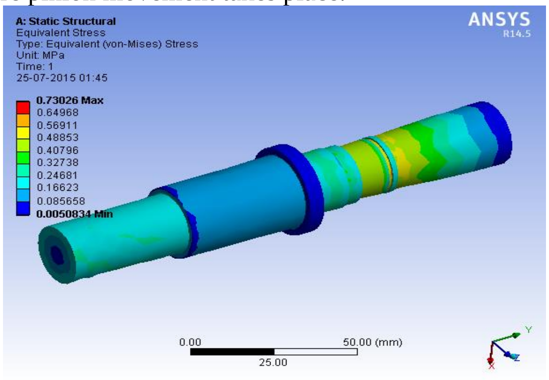

Fig.7.Static structural analysis of Input shaft

In figure 7. Input Shaft shows the Von Misses Stresses as minimum up to 0.0050834 MPa and maximum up to 0.73026 MPa. As the static structural figure shows different colours to indicate the range of stress value of the element.

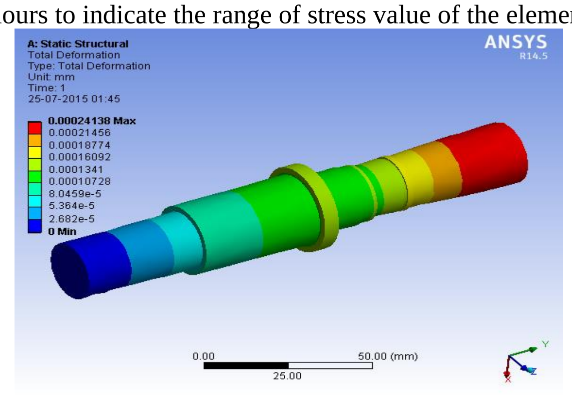

Fig.8. Input Shaft showing Total Deformation

Total deformation is shown in the fig.8.which shows 0.00024138mm is maximum deformation and minimum deformation is 0. Different shades in the figure shows different values of deformation of input shaft. Highest deformation shown at the place where gear is mounted. Maximum stress by theoretical method and Von-mises stress are well below the allowable limit, hence the input shaft is safe. Input shaft shows negligible deformation under the action of system of forces. Safe values shows that this can be suited for design purpose.

2.2.3.Load Drum

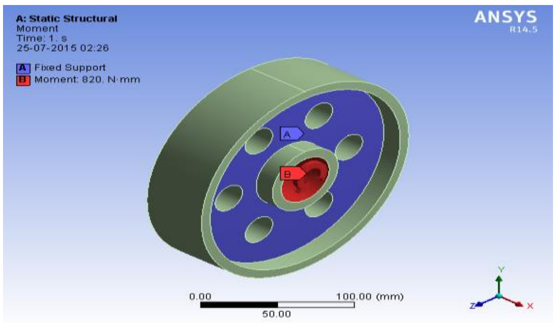

Fig.9.Boundary conditions applied to Load drum

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Drum is fixed at an inner space and moment of 820 N.mm is generated where the rotation of the drum occurred. As the load drum is rotates around the drum shaft. Power is transmitted from the motor to gear on input to the gear on drum shaft and finally to the load.

Fig.10. Static structural analysis of Load drum

Drum showing the Von mises stress as 0.1371 MPa maximum and 3.12e-6 MPa as the minimum stresses generated by software. Maximum stress by theoretical method and Von-mises stress are well below the allowable limit, hence the drum is safe. Drum shows negligible deformation under the action of system of forces.

III. ASSEMBLY AND FABRICATION OF EXPERIMENTAL SETUP

Assembly of test rig always starts from the base. So, from the base the formation of test rig starts. First base is placed at the desired place. Then with the help of welding other components are attached. Motor, frame for carrying shafts are welded neatly with the help of base. Then bearings are placed on the shafts and shafts are then put on the frame. Pulley is placed on the one end side of input shaft, then belt is attached to the motor and pulley. Load drum is placed on the drum shaft. Container for abrasive and water is welded to the frame without leakage to avoid wastage. After that pipes are applied on the funnel shaped end of container. A tap is additionally added to start and stop motion of abrasive. Extend link for carrying test specimen is welded by taking the dimension neatly from the load drum in such a way that tyre specimen will come in contact with the running drum. On the other side of extend link there is place for putting weights. After all welding is completed then the burr above them is removed by finish grinding process. All the parts then painted by oil colours to avoid corrosion.

Fig.11.Designed Model of Test rig

Individual parts of the test rigs are designed first and then assemble them as a test rig. Load drum is basically designed for doing the work of rotating road in our experiment. Whereas extend link carries the different test tyre specimen at one side and at the another side load of different weights are applied.

IV. PREPARATION AND MOUNTING OF SPECIMEN

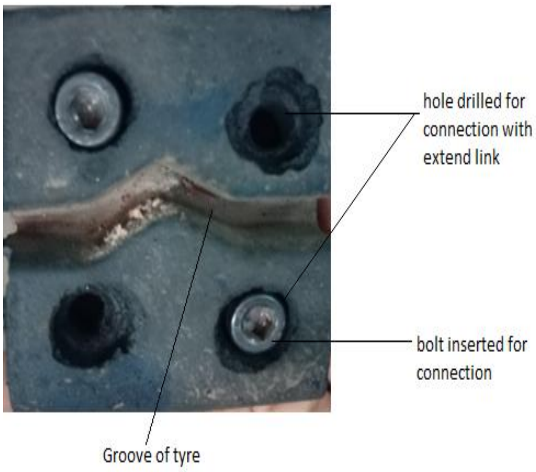

Fig.12.Prepared tyre test specimen

A small square piece of MRF radial tyre as 10×10 cm is used for the test. Four holes are drilled on that specimen to apply a space for nut and bolt to attach the test rig. 12 mm bolts and nuts are used for connection. Tyre specimen is placed such a way that the load on the tyre specimen is given on the other side of extend link. As the load on the tyre specimen increases, the speed of the tyre specimen decreases and wear rates gets increased. As the start specimen is tested for no load condition. After that weights are added and flow of abrasive is started.

V. EXPERIMENTATION

5.1. Experimental evaluation of tyre wear in dry condition

Procedure- The specimen is loaded on the test mechanism .The motor is started and the no-load speed is measured and noted using a digital contact less tachometer. At the start, extend link provide for the load has a negligible weight which is not considered. Then 100 grams of weight is added first which shows the certain speed of the drum shaft. After that abrasive material tap flow is ON. Then the abrasive falls on the space of contact between the tyre specimen and the load drum. Load drum rotates as per the motor power to the input shaft then to the drum shaft. As in our project instead of rotation of the tyre , we try a new method as rotation of the road i.e. rotation of the drum. Weight is added such that to give a load on the tyre specimen. As the specimen chosen is a square size 10cm × 10 cm. Therefore load is started from the 100 grams which is sufficient to gives the wear forms of the tyre specimen. After application of the 100 grams of weight, speed of the drum shaft was noted down. And calculation of wear dimension is carried out. Wear dimension is carried out by measuring the how much area of the tyre got wear. Wear dimension is calculated as original tyre specimen width minus remained width of the tyre

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specimen. Then wear volume and wear rate also calculated. In this way the readings of the experiments are carried out for 200 grams, 300grams, 400grams, 500grams, 600grams, 700grams, 800grams.

Table.2.Wear rate and speed values as per load applied in dry condition

Sr.No.	Load(kg)	Speed	Wear rates
1	0.1	368	1.103534
2	0.2	358	1.105401
3	0.3	344	1.59326
4	0.4	332	1.537681
5	0.5	310	1.722944
6	0.6	291	1.797049
7	0.7	284	1.753821
8	0.8	256	1.739

As the experiments are conducted repeatedly under dry conditions, that results in high friction between the tyre specimen and load drum. That's why the wear rate in the dry conditions are more. Two body abrasion shows more friction between surfaces.

5.2. Experimental evaluation of tyre wear in wet condition

Procedure- The procedure is same as the above dry condition but only one thing important is the addition of water takes place at the start of the experiment.

Table.3.Wear rate and speed values as per load applied in wet condition

Sr.No.	Load(kg)	Speed	Wear rates
1	0.1	366	1.093534
2	0.2	352	1.105401
3	0.3	338	1.43326
4	0.4	326	1.337681
5	0.5	302	1.522944
6	0.6	278	1.597049
7	0.7	261	1.553821
8	0.8	221	1.539

The experiments were conducted under wet conditions, it reveals that drum speed decreases as a result of which wear performance is found to be improved due to presence of water.

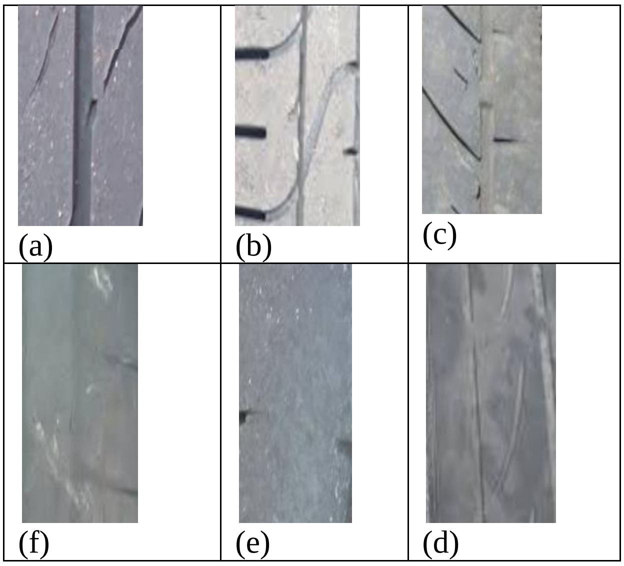

Fig.13. Showing wear rate, Where a=15% wear rate, b=30% wear rate, c=45% wear rate, d=60% wear rate, e=75% wear rate, f=100% wear rate

This wear rate is calculated by Archard's wear theory in dry condition. Dry condition is chosen because wear rate in that case is higher, so there is need to calculate the wear rate.

VI. RESULTS AND DISCUSSION

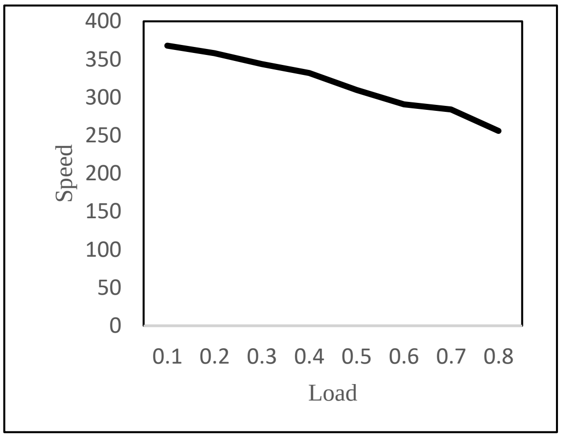

Fig.14(a)Speed of tyre specimen at given load on tyre in dry condition

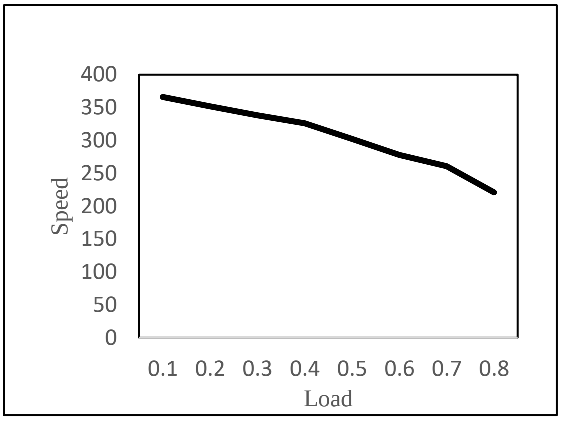

Fig.14(b)Speed of tyre specimen at given load on tyre in wet condition

Fig.14(a) and (b) shows the speed line of tyre specimen decreases as per increment in load in dry and wet conditions. But from the graph, it can see that in wet conditions the speed on the tyre is much lower than dry condition. This condition reveals that load is inversely proportional to the speed of tyre specimen. As the values of load on the tyre specimen increases, the tyre specimen gets more attached with the load drum, then due to more revolutions of the load drum, the tyre speed decreases. When there is no load on tyre, the speed of tyre is higher.

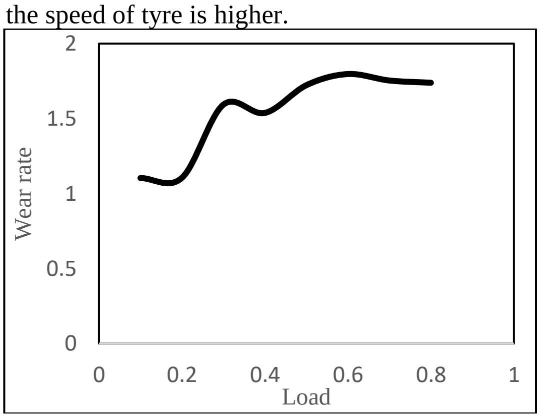

Fig.15(a) Wear rates as per load on the tyre specimen in dry condition

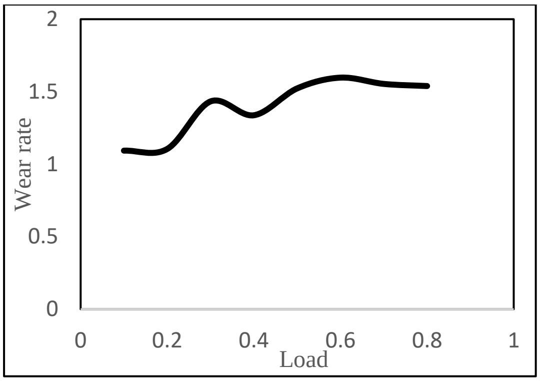

Fig.15(b) Wear rates as per load on the tyre specimen in wet condition

Fig.15(a) and (b) shows the wear rates as per load on the tyre in dry and wet condition respectively. As the wear rates are higher at the lower speeds because at that case, the load on the tyre are higher. Hence when load on the tyre increases, the wear rates are also increases. But in case of dry condition, wear rates are more whereas in wet condition the wear rates are lower.

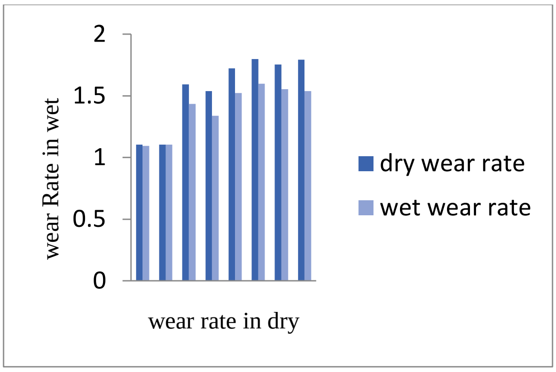

Fig.16.Comparison of wear rate in dry vs wear rate in wet

From the above graph, it is clearly seen that the wear rates in dry conditions more than the wet conditions. Due to the lubrication causes in the presence of water, the wear rates of wet conditions are lower. But in case of dry condition, only the two body abrasion takes place between the tyre surface and load drum, which results in higher friction. Hence the wear rates increases in dry condition.

CONCLUSION

From the above analysis it is seen that the wear rate is the function of the velocity and the load applied. Two body abrasion takes place between the load drum and tyre specimen which causes friction. The model uses logic to correlate tyre to the velocity of rotating drum and applied load. The model can be calibrated to known abrasive and load for calculating wear rates. The wear rate depends on the speed of the rotating drum, as the speed increases the wear rate increases. From the experiment it is proved that the tyre wear rate in dry conditions are more than the wet conditions in abrasion behavior.

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