PERFORMANCE ANALYSIS AND ENHANCEMENT OF PEUGEOT 307 TIMING BELT

In this study of Performance analysis and enhancement of Peugeot 307 timing belt, the effect of the engine speed, run time on the timing belt geometry were investigated and also a model were built to test how an engine should stop working when the timing belt cuts using sensor. The analysis, forces acting on the belt were carried out numerically. The belt failure monitoring model was achieved by the use of ultra-sonic sensor. Also an experiment was design to study the effect of time and engine speed on timing belt. The results obtained shows that the 307 timing belt have a life of 50,000 km and also that the engine speed has a positive correlation while the groove thick has a negative correlation with the engine speed.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The auto-industry is one of the important sectors of any economy. From past two decades optimum vehicle design is a prime concern in front of automobile industry. The timing drive system of an automobile is one of the most important system of an engine. The function of a timing drive is to transfer the rotation of crankshaft to camshaft and fuel Injection Pump (FIP) and other connected accessories so as to achieve proper timing at valves and the timing for fuel injection. Timing drive consisting of timing belts, timing belt/chains and timing gear drives (Aniket & Gujar, 2016).

When the engine is in motion, the dynamic forces like normal reaction forces, frictional forces, impact forces on the timing belt may cause considerable effect on the function of the camshaft and FIP shaft and hence on valve and fuel injection timing over the time.

The effect is prominent when the engine is at high speed. It was noted from the vehicle manual that, for Peugeot 307 engines, speeds ranging from 0-1500 RPM are considered as low speeds, those between 1500 - 2500 RPM are medium speeds and those above 2500 RPM are considered as high speeds. Dynamics of the timing belt drive system becoming worse as the engine speed increases and causes serious durability issues for engines, especially couple with bad road. The dynamic analysis of timing belt gives the idea of the behaviour of different components during motion and at specified conditions of working. Dynamic analysis includes computation of the forces coming on the belt, belt guides, sprockets, Plunger of tensioner.

1.2 Problem Statement

Failure of timing belt of a Peugeot 307 vehicle when in motion is a major cause of several damages like bending of valves piston crack etc. For a smaller car, replacement of timing belt would cost between (₦250000) - (₦350000), while for a larger SUV or minivan it would cost (₦350000). It is being conceived in this research work to analyse the effect of engine speed and run time of the timing belt geometry compare to the user design guide of the Peugeot 307 and to develop a model for simulating timing belt failure.

1.3 Aim and Objectives

The aim of this research work is to analyse the failure characteristics of Peugeot 307 timing belt.

The objectives are as follows:

i. To experimentally determine the effect of engine speed and run time of the timing belt geometry compare to the user design guide of the Peugeot 307 timing.

ii. To develop a model for simulating timing belt failure.

iii. To simulate the timing belt.

1.4 Justification of the Research

The solution to Timing belt failure will be of main benefit to the vehicle owners because it will minimize maintenance cost when failure occurs. Accurate prediction of effect of run time against speed will avoid timing belt failure and developing a model to prevent engine operation during timing belt failure will also minimize maintenance cost.

1.5 Scope of the Study

This Experimental research will cover two experimental factors that is the run time and engine speed so as to determine the timing belt geometry which will be conducted on Peugeot 307 engine running at idle speed because of the logistics. The belt parameters considered for this research are the belt Pitch, width, groove thickness and total height using a digital Vanier calliper.

1.6 Limitations of the Study

This research work is limited to the failure characteristics of a Peugeot 307 timing belt.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background on Timing Belt

Timing belt was first used in 1945 (Temple, 2004). Also in the 1950s, Bill Devin built a Panhard racing special with a highly modified engine using Norton Manx cylinders and heads and a toothed rubber belt driving the overhead camshaft on each Norton cylinder head. Devin’s Panhard special won the Sports Car Club of America (SCCA) National Championship in 1956 (Ritch, 2014).

The first mass produced vehicle to use an overhead camshaft engine with a timing belt was ‘The 1962 Glas 1004 (Norbye, 1984) Vauxhall Motors began production of the slant four overhead cam four-cylinder design with a timing belt in 1966 and this is been used in the vast majority of cars built today.

The timing belt connects the two most important shafts-Crankshaft and Camshaft, and ensure that these two shafts turn together at the right time. It ensures that valves and pistons are reciprocating and turning at the right time – hence the name ‘Timing Belt’

A timing belt is a part of an internal combustion engine that synchronizes the rotation of the crankshaft and camshaft so that the engine valves open and close at the proper time during each cylinder’s intake and exhaust strokes. In an interference engine the timing belt or chain is also critical to preventing the piston from striking the valves. A timing belt is usually a toothed belt – a drive belt with teeth on the inside surface. A timing chain is a roller chain.

Most modern production automobile engines use a timing belt or chain to synchronize crankshaft and camshaft rotation. Some engines instead use gears to directly drive the crankshafts. The use of a timing belt or chain instead of direct gear drive enables engine designers to place the camshafts further from the crankshaft and in engines with multiple camshafts a timing belt or chain also enables the camshafts to be placed further from each other. Timing chains were common on production automobiles through the 1970s and 1980s, when timing belts become the norm, but timing chains have seen resurgence in recent years. Timing chains are generally more durable than timing belts- though neither is as durable as direct gear drive - however, timing belts are lighter, less expensive and operate more quietly.

Timing belts are parts of synchronous drives which represent an important category of drives characteristically; these drives employ the positive engagement of two sets of meshing teeth. Hence, they do not slip and there is no relative motion between the two elements in mesh.

Due to this feature, different parts of the drive will maintain a constant speed ratio or even a permanent relative position. This is extremely important in applications such as automatic machinery in which a definite motion sequence and/or indexing is involved.

The positive nature of these drives makes them capable of transmitting large torques and withstanding large accelerations. Belt drives are particularly useful in applications where layout flexibility is important. They enable the designer to place components in more advantageous locations at larger distances without paying a price penalty. Motors, which are usually the largest heat source, can be placed a way from the rest of the mechanism. Achieving this with a gear train would represent an expensive solution.

A timing belt is a device incorporated in an internal combustion engine that connects the crankshaft to the camshaft. While the crankshaft controls the engine's pistons, the camshaft opens and closes the valves. In order to ensure optimal performance of the engine, the timing belt is fixed in the system to control the timing of crankshaft and camshaft. It is usually marked with teeth.

A timing belt is typically rubber with high-tensile fibres (e.g. fibreglass or Twaron/Kevlar) running the length of the belt as tension members. Rubber degrades with higher temperatures and with contact with motor oil.

Timing belt drive is relatively new conception of power transfer, accepted in all areas of industry today. They are flat belts with series of equal spatial teeth inside addendum diameter. Timing belt transfers the torque by means of its shape. The teeth, equally spaced at inner side of timing belts, contact the belt pulley's teeth with their hollows between teeth and, thus, by conjugate gear action, achieve the meshing between the belt and the belt pulley and transfer the torque. Considering their purpose and very important role in transmission of power and motion, it is necessary to adequately know tribological characteristics of timing belt drives. In spite of advantages in operation, timing belt drives have only recently achieved great application. It was yet after their application as internal combustion engine's camshaft drive, that their purposefulness of application had become obvious. Popularity of timing belts in automotive industry has accelerated their use in other branches of industry (Stojanovic, Tanasijevic, & Miloradovic, Trobomechanical systems in Timing belt drives, 2009)

A timing belt is important for so many reasons among which are: (i) without the timing belt, the pistons and valves fall out of synchronization and collide. This can cause a serious damage because the valves in the engine are very fragile and bend easily. (ii)

The valves need to open and close at precisely the right moment to allow the intake of air into the engine, which in turn allows the combustion of fuel and production of energy. Incorrect timing can mean limited air intake and a compromised ability to burn fuel.

There are several timing belt problems vis-a-viz:

i. Tensile failure
ii. Tooth shear
iii. Tooth wear
iv. Hallowed teeth
v. Back cracks
vi. Land wear
vii. Belt noise
viii. Edge wear
ix. Oil contamination.

A timing belt is located on the front side of the vehicle's engine and behind the plastic cam belt covers. It is designed to reduce the friction as well as generate more horsepower in an engine. The belt helps to keep the engine in check, preventing the valves from reaching and hitting the pistons.

Older belt have trapezoid shaped teeth leading to high rates of tooth wear. Newer manufacturing techniques allow for curved teeth that are quieter and last longer. Aftermarket timing belts may be used to alter engine performance. Original equipment manufacturer (OEM) timing belts may stretch at high revolution per minute, retarding the cam and therefore the ignition. (Simmons, 2009). Stronger, aftermarket belts, will not stretch and timing was preserved (Goodyear, 2010). In terms of engine design, ‘shortening the width of the timing belt reduces weight and friction’ (Mitsubishi, 2005).

Timing belts are typically covered by metal or polymer timing belt covers which require removal for inspection or replacement. Engine manufacturers recommend replacement at specific intervals (Gates, 2010). The manufacturer may also recommend the replacement of other parts, such as the water pump, when the timing belt is replaced because additional cost to replace the water pump is negligible compared to the cost of accessing the timing belt. Indicators that the timing belt may need to be replaced include rattling noise from the front of the engine. (Siegel, 2007).

Timing belts must be replaced at the manufacturer’s recommended distances and/or time periods. Failure to replace the belt can result in complete breakdown or catastrophic engine failure, especially in interference engines (Bennekom, 2005). The owner’s manual maintenance schedule is the source of timing belt replacement intervals, typically every 30000 to 50000 miles (50000 to 80000 km) (Car care council, 2008). It is common to replace the timing belt tensioner at the same time as the belt is replaced.

The usual failure modes of timing belts are either stripped teeth (which leave a smooth section of belt where the drive cog will slip) or delamination and unravelling of the fiber cores. Breakage of the belt, due to the nature of the high tensile fibres is uncommon.

Several factors have influence on the failure of the timing belt: These include (i) friction and wear (ii) tension (iii) hardware problems (iv) environmental effort (Harshal et al 2016)

In tribomechanical system of belt drive its basically requires (i) face of belt and (ii) some gaping's between belt pulley's tooth and open of belt. This system requires the direct influence on working life and power in motion transmission of the drive.

2.2 Peugeot 307

Peugeot 307 is a small family car produced by the French manufacturer Peugeot since 2001, following the Peugeot 306 which ceased production in 2002. It was awarded the European Car of the Year title for 2002 and continues to be offered in China and certain South American markets through 2014, despite the French launch of the 308(its intended successor) in September 2007 (Quicks, 2014).

The 307 makes use of a reworked 306 platform that can also be found on the Citroen Xsara as well as the 1991 Citroen ZX. However, the car is larger than the 306 in every direction. The 307 continued the company's styling first seen on the Peugeot 206 and Peugeot 607. With upswept front lights and a steeply rising bonnet leading to a highly sloped windscreen (and the upright rear doors first seen on the 206), the 307 departed from the Pininfarina-designed themes employed on the previous two generations of Peugeots, as introduced with the Peugeot 205, and ending with the (evolutionary) Peugeot 406. (Argentina Press Kit, 2010).

Its height is 1510 mm (59.4in), which is in the middle spectrum between small family cars (between 1400 and 1450mm) and compact MPVs (between 1600 and 1650mm). some consider the 307 as a low compact MPV rather than a tall small family car, because of its height and profile.

The 307 was presented as the 307 Promethee prototypes at the 2000 Mondial de l'Automobile. The production hatchback versions were introduced to the European markets in 2001 as a successor to the Peugeot 306. The 307 was also sold in Australia, New Zealand, Asia and (in 1.6 and 2.0 petrol versions) Mexico. In Brazil the 307 is sold with 1.6 and 2.0 flex (gas/ethanol) engines (Autokist, 2009).

A car engine consists of a number of rapidly moving parts which include a crankshaft, camshaft, engine valves, pistons, rods and pulleys and whenever the piston reciprocates, the valves move correspondingly (open and close),that is in and out. The crank shaft rotates or spins and the connecting rods pull and push the piston, all of this must work in perfect harmony (Dolan, 1971).

2.3 Types of Timing

There are three kinds of timing namely

i. Cam timing
ii. Ignition timing
iii. Injection timing (Dolan, 1971).

The ignition and injection timing are sometimes refers to ignition timing. The cam timing regulates the pistons and valves and the whole process is controlled by the timing belt (Dolan, 1971).

2.4 Cost of Replacement of Timing Belt

Timing belt replacement requires an advanced knowledge of mechanical systems because other components need to be removed and replaced back correctly. In order to replace timing belt correctly these steps should be followed (Gates, 2010).

i. Remove all of the parts that might be blocking your access to the engine timing belt cover.
ii. Remove the cover and inspect the materials and condition of the belt.
iii. Replace the belt with the recommended part number.
iv. Replace the water pump, tensioners and pulleys.
v. Replace the covers and components as they were originally installed.

Every vehicle has a specified period recommended for replacing the timing belt but generally it is recommended that for every 75000 miles or 5 years, depends on whichever comes first. It is equally recommended that other components such as water pump, pulleys and tensioner and front engine seals be replaced while replacing the timing belt.

For a smaller car, replacement of timing belt could cost between $300 (₦150000) - $500 (₦250000), while for a larger SUV or minivan it could cost $700 (₦350000). Most cost of replacement is accrued from labour which is between $200 (₦100000) - $900 (₦450000). A typical timing belt could cost between $25 and $50 (₦12500-₦25000) (Gates, 2010).

2.5 Timing Belt System

Timing belts are typically covered by metal or polymer timing belt covers which require removal for inspection or replacement. Engine manufacturers recommend replacement at regular intervals (Gates, 2010)

In the internal combustion engine application the timing belt or chain connects the crankshaft to camshaft(s) which in turn control the opening and closing of engine valves. A four stroke engine requires that the valves open and close once every revolution of the crankshaft. The timing belt does this. It has teeth to turn the camshaft(s) synchronized with the crankshaft and is specifically designed for a particular engine. In some engine designs the timing belt may also be used to drive other engine components such as the water pump and oil pump (Gates, 2010).

2.6 Failure of Timing Belt

The most common failure modes of timing belt are either stripped teeth which leaves a smooth section of belt where the drive cog will slip) or delamination and unravelling of the fibre cores. Breakage of the belt is uncommon owing to the nature of the high tensile fibres.

Other symptoms of a failing timing belt include rattling noises occurring from the front of the engine, retarded ignition timing and plastic chunks found inside the oil sump (Econofix, 2017).

When a rattling noise occurs in front of the engine, the belt may be loose or the timing chain. Also, when an engine jumps timing is a symptom of a bad belt. The most serious symptom revolves around finding plastic chunks inside the oil sump. The plastic chunks will be from the camshaft gears. The camshaft gears are spun by the timing belt, when the belt skips timing it can break off the camshaft to pieces, landing some of them into the oil sump. These pieces can then cause the oil pressure in the engine's bottom end to full. The loss of oil pressure will lead to engine failure and require the motor to be rebuilt (Econofix, 2017).

Some common belt problems include:

i. Friction and wear

ii. Tensile/Crimp failure

iii. Tooth shear

iv. Tooth wear

v. Back cracks

vi. Oil contamination

vii. Belt noise

2.6.1 Friction and tooth wear

Considering tribo-mechanical systems in timing belt drive, it's basically required: (1) belt's tooth and belt pulley's tooth, (2) Face of belt and flange, (3) some gaping's (space) between teeth of the belt and apex of the belt pulley's tooth as shown in Plate I. Analysis of these tribo-mechanical systems shows that the influence of the friction forces that occur in them may not be neglected and directly influences the power and motion transmission and working life of the drives (Stojanovic, *et al.,* 2009).

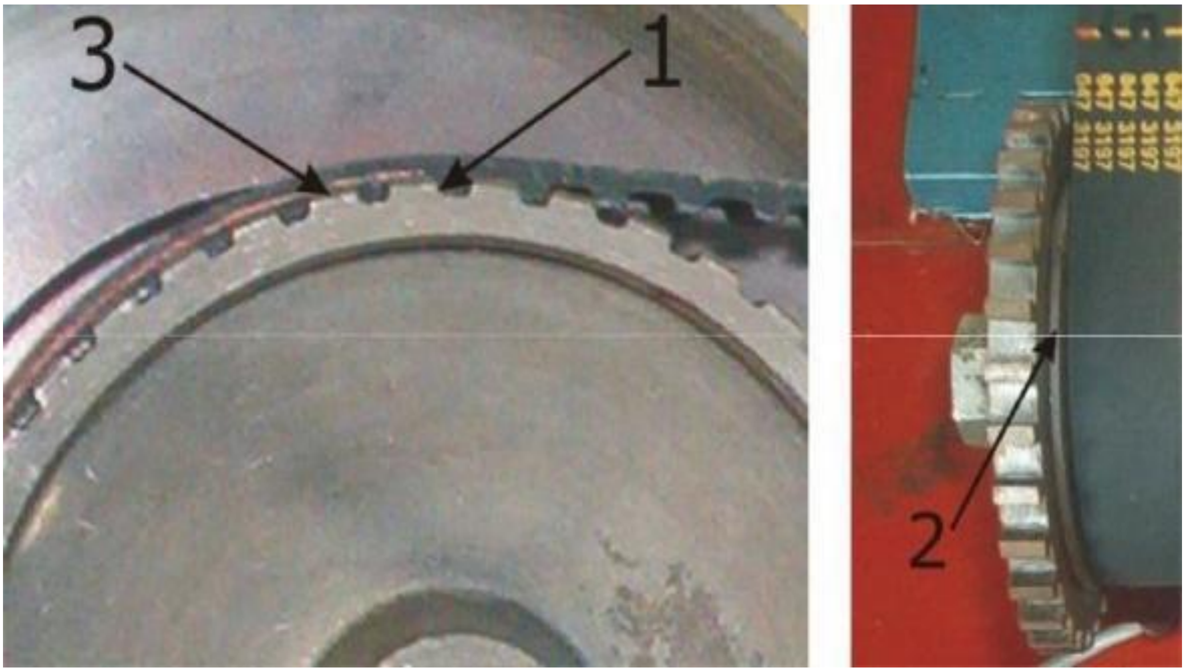


Plate I: Timing belt drive and basic tribo-mechanical systems (Stojanovic and Blagojevic, 2011)

Values of the friction force are different for all three analysed tribo-mechanical systems. Friction force has the largest values at the side surface of the belt's and the belt pulley's teeth. Friction force has somewhat smaller values between belt's face surface and flange, while the lowest values are between the apex of the belt pulley's teeth and the space between belt's teeth. Direction, sense and intensity of these forces are related to kinematics of couplings in timing belt drives. (Childs, 1997)

2.6.2 Tensile/crimp failure

The belt's tension has an important part in design of the timing belt drive. Proper belt's tension provides normal coupling between the belt and the belt pulley, minimal losses in the drive, smaller wear in bearings and smooth operation of the drive. The belt should be pretension according to the producer's recommendations. Checking of the belt's tension is done by tensiometer. Inadequate belt's tension reflects as insufficient or exaggerated belt's tension. Exaggerated tension of the belt leads to increase of power losses at idle speed and reduces the efficiency. In addition, if the belt is over-tensioned, drive element's fibres are additionally loaded in view of their strength, which leads to sooner cracking of the drive element as shown in Plate II. (Dudziak, 2008)

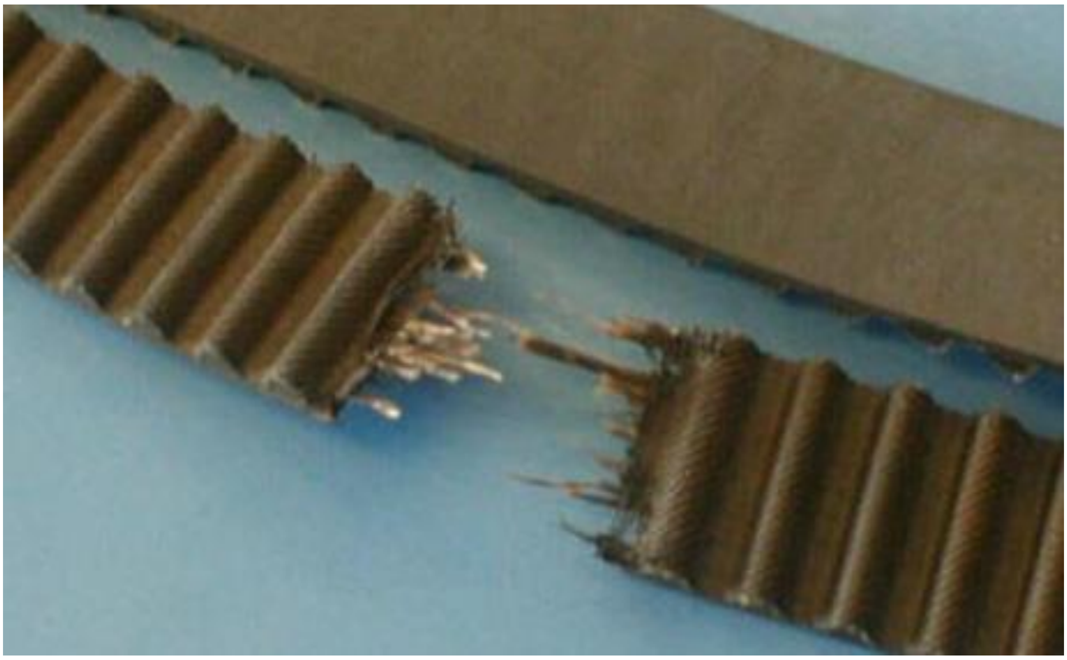


Plate II: Cracking of the drive element
(www.researchgate.net/publication/271705831)

Increase in belt's tension directly influences the kinematics of coupling between the belt and the belt pulley. Hence, cracks appear in the belt's tooth root on the side, which is in contact with the belt pulley's tooth (Johannesson, 2002).

Besides, the teeth's contact surface decreases, which additionally loads neighbouring teeth on which the cracks in the roots have appeared. Due to over tension, there is more intensive wear of the belt's surface layer, until the driving element becomes visible. Over-tension, as well as insufficient tension of the belt, may lead to too early failure of the timing belt drive.

It's an obvious situation that if the tension on a belt is slightly higher up, cords of the belt will simply not resist it and not supporting enough loads on it. Bending of localized cords caused de-bonding within them, which resulting as huge reduction on its tensile strength so as abrasion of interfilament of loading those cords as shown in Plate III. (Milanović I. , 2010)

It damages mishandling of belt drive in adequation of drive while installation higher tension and minimal diameters of sprockets. Belt drive mishandling can happened from improper sort off packaging and on a storing. Some foreign objects located in between sprocket and belt resulted as crimping. Belt drive riding out of sprockets while working under some tension, which is an acceptable belt drive tension named as "Self-tensioning", and also riding out grooves of those sprockets helped to increasing in tension of span on approachable at tighter side in grooves. Those minimal diameters also ended with resulting in crimping and bending belt drives. If tighter side not forced enough then it will working as a ratchet & teeth's will back down which also resulted in tooth damage (Milanović, 2011).

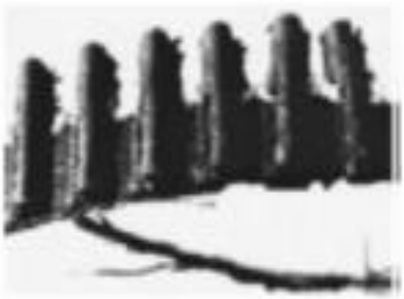


Plate III: Cord elimination (Gates, 2010)   Plate IV: Crimp failure (Gates, 2010)

2.6.3 Tooth shear

When in any of the driven equipment, regular cyclic loads and higher than a normal intermitting of belt drives are generated shock loading or shocking load has occurred. Also ended with higher than normal stresses of belt this failure of belt will act as a catalyst. Sometimes it will end up with some unwanted appearances and belt breaking under a ragged shown in Plate IV. Also in V-belt conventional belt drives slips under some higher amount of loading torque condition where synchronized belts must have transmitting their peak loads and Magnitudes.

This could also be as a result of incorrect tension and worn pulleys. Corrective measures are replacing pulleys and install at correct tension. (Dudziak, 2008)

Plate V: Crack in the belt tooth root (www.researchgate.net/publication/271705831)

The crack in the root of the firstly loaded tooth spreads towards the apex of the tooth and leads to its shearing as shown in Plate V (Domek, 2011).

Plate VI: Shear in the belt tooth root (www.researchgate.net/publication/271705831)

2.6.4 Tooth wear

Tearing or root crack at the tooth occurring failures in the side of the belt. It operated on drives misalignment of the shaft which wears of unwanted pattern across tooth of the belt and compacting of flanks in the areas of belt land drives. Right at the edge of belt drive there's some significant tracking force and wear down at one side and rolled up for sprocket flanges -Plate VI with some parallel misalignment on sprockets flanged region which is operated by belt have some additive edged wear and pinched on an opposite side of flanges. There's also full operating load developed as shown in concentrated region of Plate VII. Carried by non-flanged sprockets where tooth unworn on it. Coaxiality of the shaft and the belt pulley has a great influence on the working life of the timing belt drive. If there is no angular coincidence of the axes of the drive's shafts, then the contact surface area between the belt's teeth and the belt pulley's teeth reduces. One side of the tooth was more loaded than the other. This load may lead to appearance of intensive wear of the belt and the belt pulley and to rapid damage or failure of the belt (Stojanovic, 2009).

Another problem due to lack of coaxiality is one face of the belt is loaded more. Due to lack of coaxiality, the face surface was firmly leaned against the flange and then there comes the abrupt damage of the face surface of the belt as shown in Plate VIII. These damages spread towards the centre of the belt, reduce the contact surface, additionally load the nearby teeth and lead to rapid failure of the belt. Due to lack of coaxiality of the shafts, there appear the increase of unevenness of drive's operation, increase of noise and vibration and even the falling off of the belt from the belt pulley. (Stojanovic, 2010).

The belt's damage also appears due to the belt pulley, which dimensions deviate from design documentation. If diameters of the belt pulleys or teeth are not manufactured with corresponding tolerances, large damage of the belt appears. These deviations lead to damage of protective surface layer of the belt. Damage appears in all directions, they were not distinctive and they look undefined related to the belt pulley's design. Namely, if the belt pulleys are manufactured with flanges, then the increased wear of the belt pulley appears due to over-tension of the belt. Intensive wear of the belt additionally loads the belt pulley's teeth, directly leaving the trace on the belt pulley. Due to extensive wear, the drive element becomes visible and then there is a metal-on-metal contact, which may lead to abrasion and rapid damage of the belt pulley (Domek, 2011).

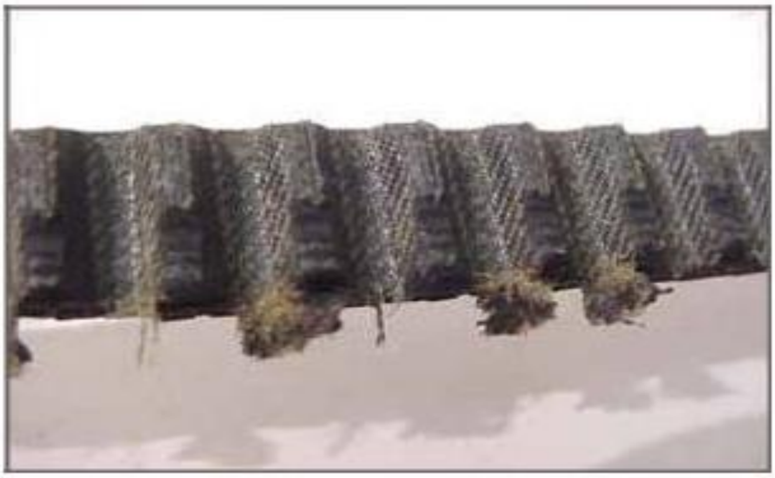


Plate VII: excessive edges wear (Gates, 2010)

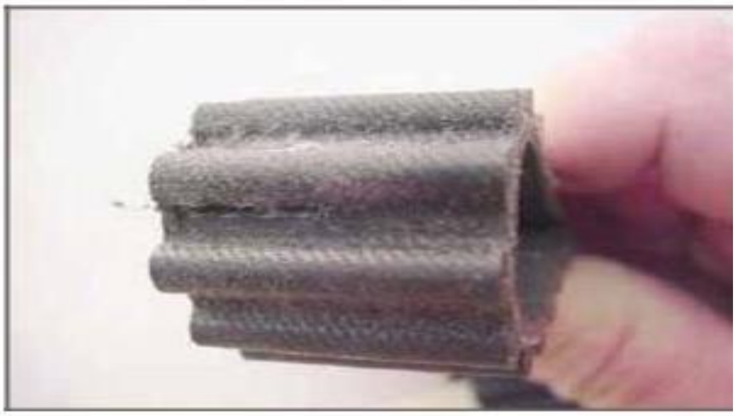


Plate VIII: Uneven belt wear (Gates, 2010)

Plate IX: Damage of the face surface of the belt
(www.researchgate.net/publication)

2.6.5 Back cracks

The timing belts are especially sensitive to high temperatures, action of chemical compounds and foreign bodies. Materials used for making of the belts are rubber, urethane (polyurethane), and neoprene and similar that is more or less not resistant to high temperatures. When rubber belts work at high temperatures for a long period, rubber compounds gradually harden, losing their features. The cracks appear at the back surface of the belt, parallel to space between teeth of the belt. These cracks lead to the cutting off of teeth and to cracking of the drive element. For prolonged period of time higher grade than 185°F rubber belts operates as shown in Plate IX, this compound interest in gradually back cracking. The construction of this belt is available in higher environment temperature to improve their provided services. Polyurethane compound of carbons at the excessive temperature of 185°F subjected to an environmental system. As shown in Plate X. High operation been performed on a chemical compound of polyurethane at a given melting point which occurring some loses of integrity inside.

Plate X: Back crack (Stojanovic, 2011)

Plate XI: Melting from high temperature operation (Stojanovic, 2011)

2.6.6 Oil contamination

Materials of the timing belts are highly sensitive to oils and solvents. There is a large number of chemicals that may come into contact with the belt (antifreeze, fuel, lubricant and similar). Under the action of chemical solvents, the belt reacts similarly as under the action of high temperatures. Rubber compounds harden and the back surface cracks. The timing belt drives are highly sensitive to the presence of foreign bodies between the belt and the belt pulley. The presence of such bodies leads to heavy damage of the belt, especially the drive element. As soon as the part of the drive element is damaged, the rest is additionally loaded which leads to rapid failure of the belt. Action of the foreign bodies lead to damage of the belt pulley in the form of cuts and scratches, so replacement of the belt pulley is necessary. (Milanović, 2011)

2.6.7 Belt noise

Belt noise is caused as a result of high tension, low tension, misalignment and damaged flange(s). Corrective actions include: correct alignment, replacing pulleys and installing at correct tension. (Milanović, 2011)

2.7 Timing System Component Identification

Engine timing systems utilize one or more of following components: idler or pulley, tensioner, hydraulic damper pivot arm and water pump as shown in Plate XII below

Plate XII: Timing components (Auto, 2017)

Tensioners and idlers are important components that work hand-in-hand with the timing belt. If there is damage to a timing belt, Gates recommends that these parts be changed as well. Belt damage can occur from:

i. Too much or too little tension
ii. Vibration
iii. High temperature
iv. Belt misalignment

When replacing any timing component, including tensioners, always refer to the vehicle's service manual.

After installation, always take a few extra minutes to look over all the components and check for proper operation. Make sure the pulleys rotate freely, check the belt tension and make sure bolts are tightened to the recommended torque values. (Stojanovic, 2009).

2.7.1 Idlers and pulleys

The timing belt system uses idlers and/or pulleys to either change the direction of the belt or transmit power to a component such as a water pump or oil pump. Pulleys and idlers are either Smooth (Plate XIII) located on the back side of the belt and typically used to change the direction of the belt to provide more wrap, or teeth in mesh, on a sprocket. They are also used to break up long spans to prevent belt flutter or Notched (Plate XIV) also called sprockets, are located on the tooth side of the belt and exactly match the tooth profile of the belt.

Plate XIII: Smooth pulley (Auto, 2017)

Plate XIV: Notched pulley (Auto, 2017)

Note: Do not mix or match sprockets from similar makes and models during replacement. Only replace sprockets from a quality supplier for the specific application.

Pulleys are constructed of metallic or plastic material and a sealed bearing. The pulley bearings are a “wear” item and must be changed at regular intervals. Bearings are lubricated with premium grease and sealed at the factory to extend bearing life. On used bearings, be sure to look for seepage from the pulley bearing and examine the condition of the seal. If you’re ever in doubt, replace the pulley. Also, check the condition of the bearing by checking for “roughness” when turning. Never clean bearings or add lubricants as this will shorten bearing life. (Gates, 2010)

2.7.2 Tensioners

Timing belt drives use three types of tensioning devices that must be installed per the vehicle manufacturer’s instructions: manual tensioner, spring loaded tensioner and hydraulic damper pivot arm (Gates, 2010)

2.7.3 Manual tensioner

Manual tensioners as shown in Plate XV uses a tension spring to apply the initial tension. One end of the spring is hooked to the tensioner and the other end to the engine and the tensioner bolts is tightened to the proper torque required. (Gates 2010)

Plate XV: Manual Tensioner (Auto, 2017)

2.7.4 Automatic spring-loaded tensioner

This is also known as a “frictional” tensioner, manufacturers are increasing their usage each year of the automatic spring-loaded tensioner because it provides a more consistent belt tension that can react and adjust to today’s high-revving engines. Gates carries an extensive line of these tensioners, many of which were only available through the OEM until now.

Proper installation of these tensioners is critical and installation instructions must be followed. Once installed, belt installation is generally very simple. In most cases a hexhead wrench is used to rotate the tensioner into a position that permits the belt to slip into place. Once the belt is in place the tensioner is allowed to return to its operating position, applying the necessary tension. (Gates 2010)

Figure XVI: Automatic Spring-Loaded Tensioner (Auto, 2017)

2.7.5 Hydraulic damper pivot arm

Several engine manufacturers use a pivot arm in correlation with a hydraulic damper to tension the belt. This damper uses a piston that pushes a pivot arm with a pulley, providing the required tension. When re-using the hydraulic damper, the piston will need to be driven back into its cylinder and locked in place. A vice can be used to retract the piston. Simply remove the damper from the engine, place it between vice jaws and slowly compress the piston. Once compressed, line up the holes in the piston with the holes in the cylinder and insert a pin to hold the piston in place. The Gates Pin Set is the only tool created just for this purpose (Part No. 91010). (Gates 2010)

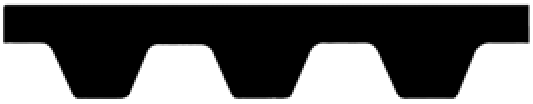
Plate XVII: Hydraulic Damper Pivot Arm (Auto, 2017)

2.7.6 Tooth profiles

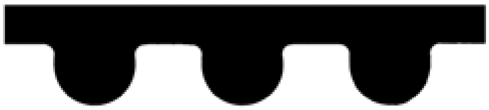
The earliest timing belts had a trapezoidal tooth profile. Competition and more demanding applications led to the development of a curvilinear profile. This in turn, evolved into a modified curvilinear profile. Belts with different tooth profiles are not interchangeable. Gates has the most complete timing belt line available, with more than 450 part numbers.

The line includes both neoprene and HSN (highly-saturated nitrile) constructions, and all three tooth profile types (Gates 2010).

- Trapezoidal



- Curvilinear



- Modified Curvilinear

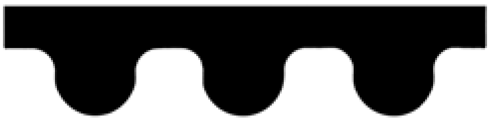


Plate XVIII: Timing Belt cross section.

Neoprene was standard until 1985, when Gates introduced the first belts made of HSN. In short supply, and difficult to engineer, HSN was the material of choice for most new timing belts. An HSN-constructed belt appears no different than a neoprene belt, but significantly outperforms in the high-temperature engine compartments of modern vehicles.

In 2000, OEMs began using upgraded materials in timing belts, and Gates followed on aftermarket belts. While the name remained the same, this newer HSN is higher-grade on all drives requiring an upgrade.

Rubber was not the only improvement made to timing belts; the cord and jacket material were upgraded as well (Gates 2010)

2.8 Review of Related Work

In the study by Stojanovic 2011 monitoring the roughness parameters in the period of working out, decrease after 5 hours of operation may be noticed. Already in the next phase of the period of working out (5 to 10 hours of operation), monitored roughness parameters increase. In the first 5 hours of operation, the highest roughness peaks are being flattened, so the profile gets more even. However, in this research, time was only considered in which the engine speed was supposed to be varied as it also affect the belt.

Ucar (2012), in a study, on novel failure diagnostic system for timing belts was developed in order to prevent a catastrophic belt failure. These failures may occur before running out the nominal belt life and lead to an extensive engine damage, thereby resulting costly repairs. Three optical sensors with laser beam whose diameter is 0.6 mm was located on suitable positions and it is used to produce error signal resulted from disturbance of laser beam flows due to failure. The error signal is processed by the processor, which is independent from the electronic control unit (ECU) to alert the driver or ECU, directly. Experimental apparatus which consists of two camshaft pulleys and an idler pulley with belt tensioner has been set up to simulate real engine conditions. Experimental results show that the optical monitoring technique is reliable to determine timing belt failure types simultaneously in the range of 500–7000 rpm engine speed and none of the sensor stop the motion.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description / Working Principle

This section presented the methods and the materials used during the course of this research work. The method covers the technique used for the experimentation, analysis and simulation of the timing belt. In an engine, the crankshaft drives the camshaft(s) and actuates the valves via a belt. The timing belt is widely used by car manufacturers because of its advantages, namely reduced space, as well as lighter and quieter running. Engine timing is everything, responsible for synchronizing the crankshaft to the camshafts, the timing belt is essential for keeping your engine running smoothly and efficiently as indicated in Plate XIX. It ensures that all the necessary valves open and shut on cue with the pistons.

Today, one out of every five passenger cars and light trucks use a timing belt to transmit power from the crankshaft to the camshaft(s). Most 4-cylinder uses a timing belt. The timing belt is critical to the engine because it sets the engine's intake and exhaust valves in motion.

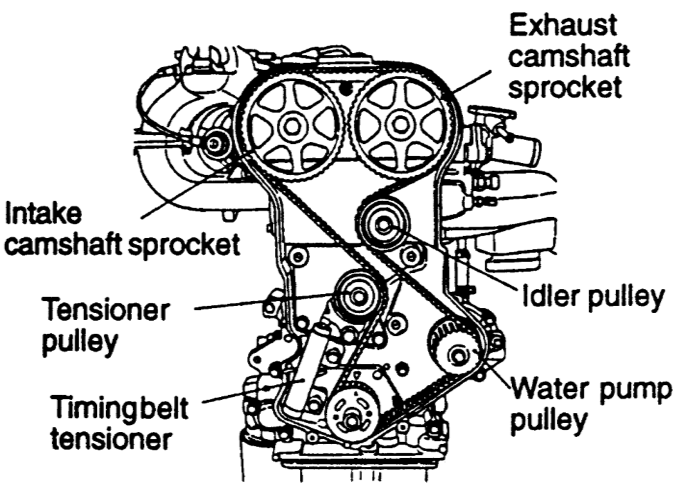


Plate XIX: Engine timing system parts identification (Auto, 2017)

Care must be taken to ensure that the valve and piston movements are correctly synchronized. Failure to synchronize correctly can lead to problems with valve timing, and this in turn, cause collision between valves and pistons in interference engines and causes the valve to bend as shown in Plate XX.

Plate XX: bent valve (www.ssch.com.au)

In the modern approach to projecting, the use of simulation at the different levels of the projecting process can verify the function in the real conditions, the tension of the parts and ability of carrying the load. In recent years, modern software packages provide us with an opportunity to perform all those calculations on the different types of load fast and easy. For calculation and analysis of timing belt transmitter in this paper, at different values of the load, the finite elements method applies. The analysis of the impact of pre-tensioning on the load distribution at timing belts in this paper is analysed in this paper by MKE integrated in 3D software package Autodesk Inventor. The analysis of the impact of pre-tensioning is performed for real timing belt drive.

The complete profile of the timing belt with belt pulley which is used in the analysis has been

Modelled and analysed in 3D. Figure 6 presents the examination model of timing belt drive with the network of finite elements. (Milanović I. , 2010).

3.2 Materials used

i. Crank shaft pulley with 20 teeth

ii. The timing belt used in this study has 140 teeth with a width of 24.76 mm and a pitch of 13.46 mm.

iii. High speed AC motor with power of 0.7 kW at the speed of 3500 rpm

iv. Two cam shaft pulleys with 40 teeth each

v. Proximity sensors

vi. Digital Vanier calliper

vii. Peugeot 307 vehicle

viii. Test Bench

ix. Software (Solid work and Von messes)

Testing of timing belt drive was conducted on a test bench designed on purpose and made. Test bench operates on a principle of opened loop power.

Basic elements of the test bench are:

a) Driving unit;

b) Cardan transmitter;

c) Input shaft;

d) Sensor for input shaft number of rotation;

e) Torque sensor on input shaft;

f) Analysed timing belt;

g) Output shaft;

h) Mechanical brake;

i) Tension mechanism

j) Signal amplifier.

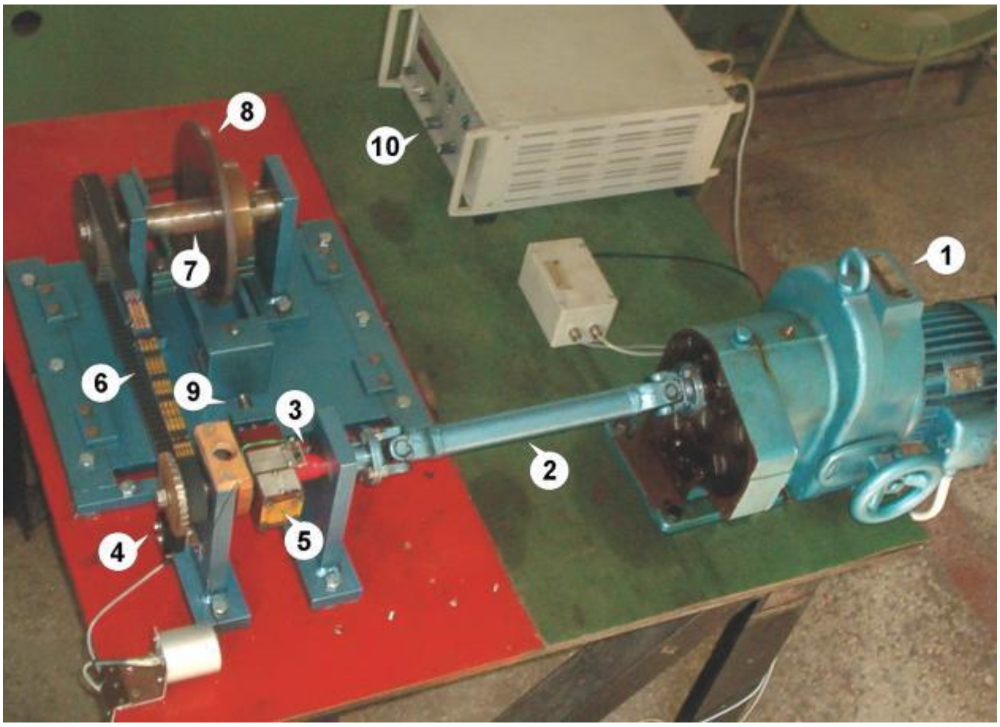


Plate XXI: Test bench for testing of timing belt

3.3 Design Consideration

The test frame was designed to simulate the operation of an internal combustion engine timing belt failure. The timing belt used in this study has 140 teeth with a width of 24.76 mm and a pitch of 13.46 mm. Crank shaft pulley with 20 teeth was driven by a high speed AC motor with power of 0.7 kW at the speed of 3500 rpm. Two cam shaft pulleys with 40 teeth were driven by the crank shaft pulley through the timing belt. In this study the most important design criteria is the sensor locations so as to sense the timing belt failure and stop the engine from operating and thereby minimizing the valves from bending.

3.4 Research Theory/Calculations

In the analysis of the timing belt, Plate XXII, the first tooth meshing with the belt pulley is denoted as $i = 1$. Due to the increase in the angle of rotation, moving to the next position, belt tooth obtains increasing number until the last tooth in the coupling, which is denoted as $i = n$.

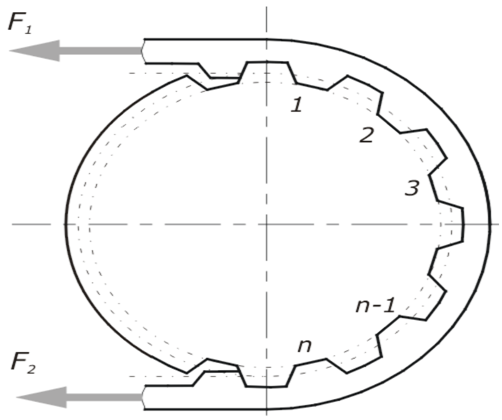


Figure XXII: Belt meshing with belt pulley (Stojanovic, 2009)

Tension of the belt due to the load transmission changes from $F1$ to $F2$, that is, tension in tractive and free section. Forces on the timing belt and driving pulley, which occur during the meshing, as well as the resistances that is., friction forces, are presented on Plate XXIII. The procedure of belt teeth meshing with belt pulley is relatively complex and is carried out through several steps. The side of the belt tooth i from Figure 3.2 is influenced by the force F_B.

Force F_B has a significant impact on the load distribution; it is balanced by the forces F_{i-1}^{*} and F_i and these forces intersect at the point S (Figure 3.3).

Force F_B is calculated as: $F_B = F_i - F_{i-1}^{*}$ (3.1)

Where: F_i is force on the belt tooth *i*; and

F_{i-1}^{*} = force on the tooth of *i* =1 belt pulley

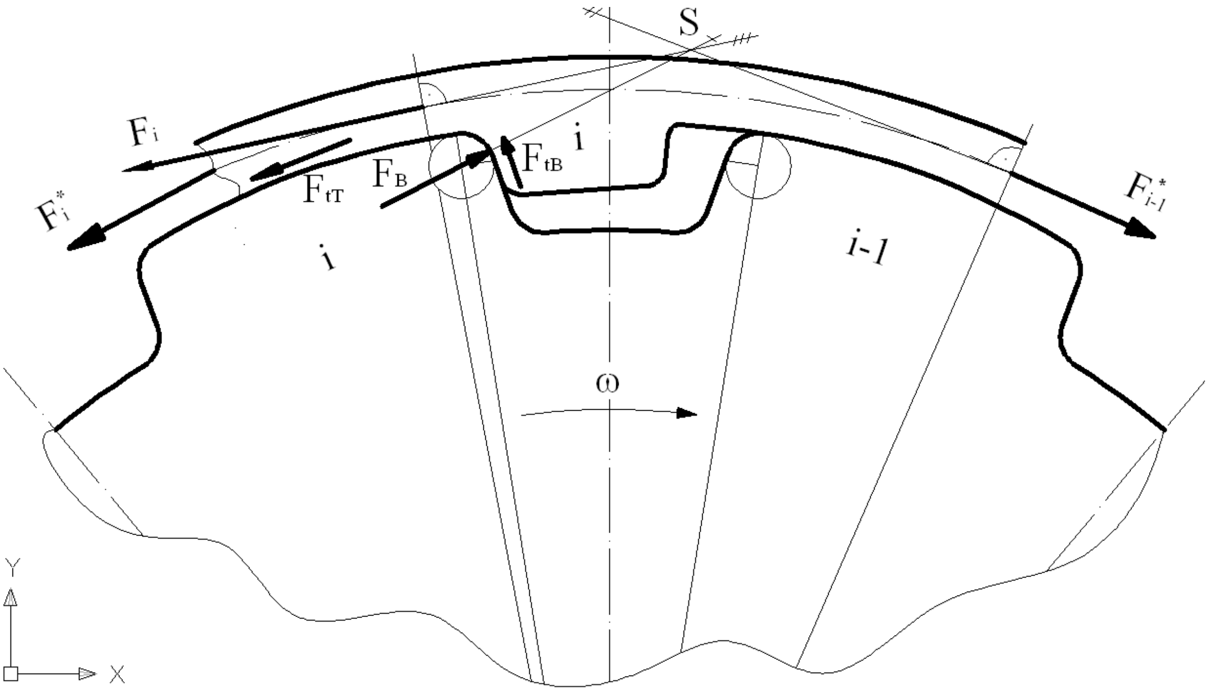


Plate XXIII: Forces and resistances on the belt and driving pulley due to meshing (Karolev, 1995)

Because of the contact of belt inter-teeth and belt pulley tooth top land, the frictional force, which can be calculated in the following way, is introduced:

$$F_{tT} = F_i^* - F_i \tag{3.2}$$

Where:

F_i^* - Tension force of belt teeth i;

F_i - Tension force.

An extensive force transmitted by belt tooth i according to expressions 3.1 and 3.2 can be expressed as: (Karolev, 1995)

$$F_T = F_{tT} + F_B \tag{3.3}$$

Based on the identified typical places where resistances occur at meshing, for the purpose of explanation of load distribution the corresponding model with springs is formed (Johannesson, 2002).

In the previous part of the paper are mentioned two friction forces, and in such way are also positioned the springs on those typical places where resistances when moving will occur.

The simplified model of the transmitter elements, with placed springs on the places of the belt and belt pulley contacts is presented on the Plate XXIV

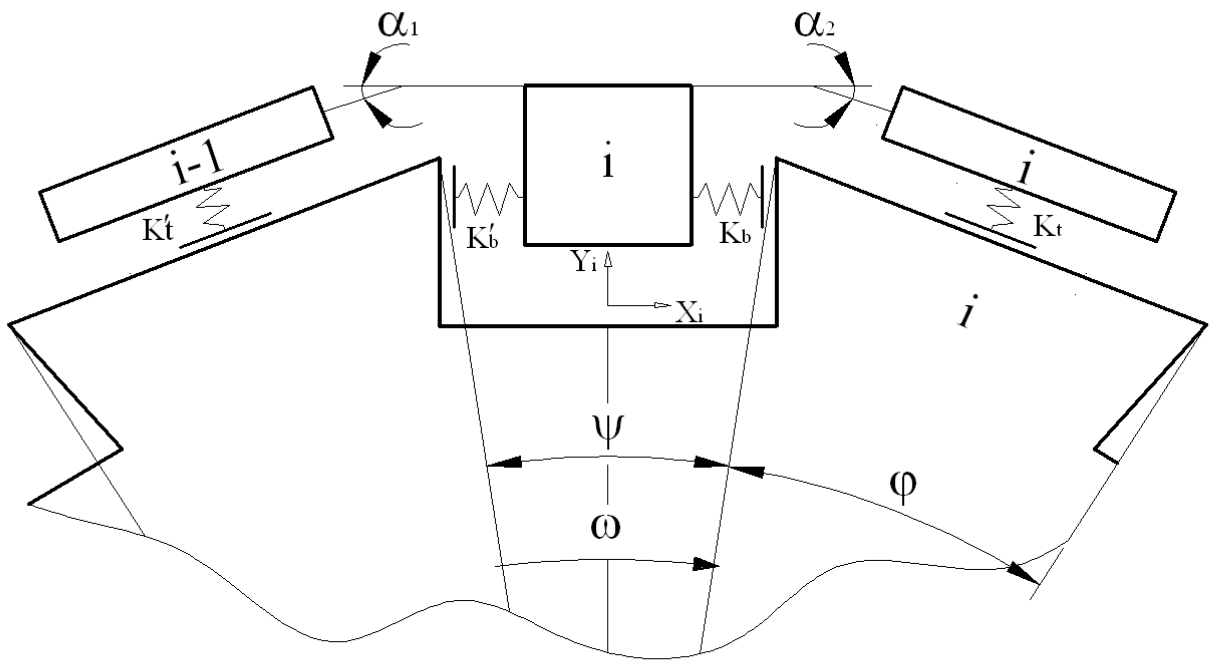


Plate XXIV: Basic model of the belt with belt pulley (Gerbert, 2010)

It is important to mention that the belt pulley is significantly more rigid compared to timing belt, and due to the contact the large deformations of the belt occur. For the mode presented on Plate XXIV, the equilibrium equations are established. Equilibrium equations are very complex for calculation, therefore is necessary to adopt certain simplifications in order to obtain results. Therefore, if it is adopted that angles $\alpha 1$ and

$\alpha 2$ are known, the defining of remaining geometry in the model of transmitter is significantly simplified as well as the further calculation.

Resolving of the equilibrium equations leads to the values of radial, normal forces and tangential normal forces on the tooth. The rigidity of the springs is known, and on the basis of their deformation, that is, displacements that occur at the contact of the belt and belt pulley it is possible to determine the friction forces on the points of the contact. Depending on the point of the contact, the friction defines in the following way: (Krumi & Gupta, 2008)

3.4.1 Friction in the contact of the belt inter-teeth and belt pulley top land

$$F_{tT} = \Delta_t \ . \ K_t \qquad (3.4)$$

Where: Δ_t - deformation at the contact of belt inter-teeth and belt pulley top land,

K_t - The rigidity of the spring at the contact of the belt inter-teeth and belt pulley top land.

3.4.2 Friction in the contact of the sides of belt teeth and belt pulley teeth

$$F_{tB} = \Delta_b \ . \ K_b \qquad (3.5)$$

Where: Δ_b - is deformation due to the contact of the sides of the tooth,

K_b - the rigidity of the spring on the sides of the belt teeth and belt pulley. (Callegari, 2011)

Steel is used as a material for belt pulleys, and for the belt, since it doesn’t contain tractive element, the hard rubber is used.

Properties of the materials of the belt and belt pulley are presented in the Table 3.1.

Table 3.1: Basic properties of the material (Stojanovic, 2009)

Material	Young modulus	Poisson's coefficient
Steel (belt pulley)	210 GPa	0.3
Hard rubber (belt)	10GPa	0.3

When the timing belts of most engine system are compromise, this affect the valve arrangement and may have other side effects to the engine. The model to demonstrate this phenomenon is presented in appendix A. The model was developed in two phases that is arrangement of mechanical components and the electrical control.

The experimental setup comprises of a Peugeot 307 vehicle, a timing belt and a digital veneer calliper. It is desire to measure the timing belt wear as it run over a time period. Therefore, the table used to conduct the experiment was presented in the table 4.1. The Vanier calliper was used to record the geometric defects on the timing belts as it run over the time period, the speedometer on the dash board were used to record and set the engine speed at 1000 rpm, 1500 rpm and 2000 rpm for a period of four (4) hrs each. The images taken during the experimentation was presented in Plate 3.2

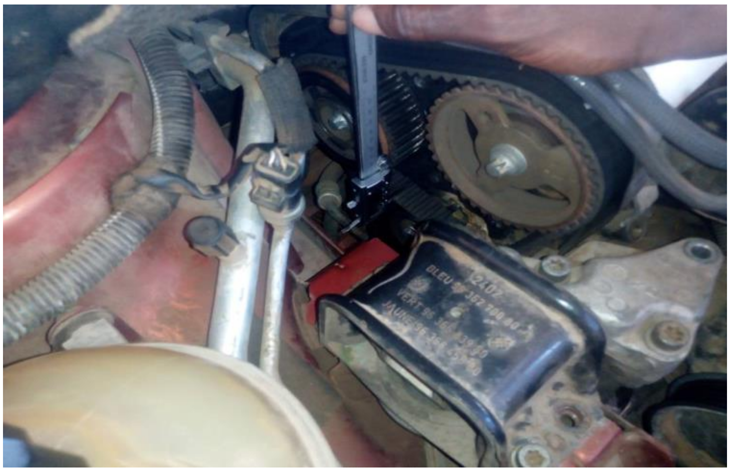


Plate XXV: Measurement of belt Geometry

3.5 Fabrication

The model was fabricated using components of the timing belt shown Appendix A and arranged on a board as schematically. The model was covered using a transparent plastic sheet and the pulleys-belt arrangement was placed on the plywood board. The engine drive pulley where connected to the AC motor. Bolts and nuts were used for the joints.

The electrical part was used to control the operation of the timing belt whenever there is failure. Two proximity sensors were used to sensing the presence and continuity of the timing belt, while the other sensor was used to ensure that the cover is in place before the model can operated. An AC motor were used to provide the RPM during operation. The constructed circuit is shown in Plate XXVI.

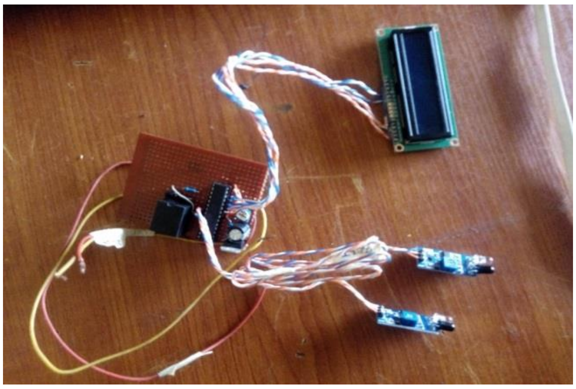


Plate XXVI: The electrical circuit

3.6 Testing

3.6.1 Testing the model

To test the model developed, the timing belt was put in place and tension to the desired level, then the cover was closed and the electric motor switched on and run until the belt cut. The procedure was repeated 5 times.

3.6.2 Testing of timing belt drive

Mechanical brake provides a given amount of brake torque that is load torque on output shaft of the timing belt drive. Value of the load torque is obtained by readout of a display of digital amplifier bridge which obtains the torque signal from a measuring shaft, through signal preamplifier HBM EV2510A. Rotational speed of input shaft is also read on the amplifier bridge which obtains the signal through inductive sensor and impulse signal receiver of number of revolutions, HBM DV2556. Thus, regime at the input shaft of the driver is defined In order to obtain a true picture on tribological characteristics of the timing belt, measurement of roughness parameters and determination of geometrical values are conducted. Measurement of these values is conducted according to previously determined dynamics. (B. Stojanovic et al 2010).

3.7 Simulation (Solid work and Von messes)

Step 1: Creating the Geometry -

Step 2: Creating a Study - The first step in performing analysis is to create a study. Then;

1. Click Simulation, Study in the main SolidWorks menu on the top of the screen. And the Study Property Manager appears.
2. Under Name, type study name.
3. Under Type, select Static.
4. Click OK.

Step 3: Assigning Material: All assembly components are made of different materials. i.e belt materials, alloy Steel e.t.c. Assign Alloy Steel to the pulleys and fabrics to the belt materials. To apply materials from the SolidWorks Simulation Manager tree;

1. Right-click the Parts folder and click Apply Material to All. The Material dialog box appears.
2. a) Expand the SolidWorks Materials library folder. b) Expand the Steel category. c) Select Alloy Steel
3. Click Apply.
4. 4 Close the Materials window.

Step 4: Applying Fixtures -

1. Use the Arrow keys to rotate the assembly so as to apply the fixture to the fix parts.
2. In the Simulation study tree, right-click the Fixtures folder and click Fixed Geometry. The Fixture Property Manager appears.
3. Make sure that Type is set to Fixed Geometry.
4. In the graphics area, click the faces of the three holes, indicated in the figure below. Face, Face, and Face appear in the Faces, Edges, and Vertices for Fixture box.
5. Click Fixed fixture is applied and its symbols appear on the selected faces. Also, Fixed -1 item appears in the Fixtures folder in the Simulation study tree. The name of the fixture can be modified at any time.

Step 5: Applying Loads We will apply a 2250 N force normal to the face

1. Click Zoom to Area icon on the top of the graphics area and zoom into the tapered part of the shaft.
2. In the SolidWorks Simulation Manager tree, right-click the External Loads folder and select Force. The Force/Torque Property Manager appears.

3. In the graphics area, click the face shown in the figure. Face appears in the Faces and Shell Edges for Normal Force list box.
4. Make sure that Normal is selected as the direction.
5. Make sure that Units is set to SI.
6. In the Force Value box, type 2250.
7. Click SolidWorks Simulation applies the force to the selected face and Force-1 item appears in the External Loads folder.

Step 6: Meshing the Assembly Meshing divides your model into smaller pieces called elements. Based on the geometrical dimensions of the model SolidWorks Simulation suggests a default element size (in this case 4.564mm) which can be changed as needed.

1. In the Simulation study tree, right-click the Mesh icon and select Create Mesh. The Mesh Property Manager appears.
2. Expand Mesh Parameters by selecting the check box. Make sure that Curvature based mesh is selected. Keep default Maximum element size, Minimum element size, Min number of elements in a circle and Element size growth ratio suggested by the program.
3. Click OK to begin meshing

Step 7: Running the Analysis in the Simulation study tree, right-click the My First Study icon and click Run to start the analysis. When the analysis completes, SolidWorks Simulation automatically creates default result plots stored in the Results folder.

Step 8: Visualizing the Results von Mises stress

1. Click the plus sign beside the Results folder. All the default plots icons appear.

2. Double-click Stress1 (VonMises) to display the stress plot

3.8 Measurement of Geometrical Parameters

In addition to measurement of geometrical values, measurement of roughness parameters is conducted during testing of the timing belt. Measurement of geometrical values of timing belts was conducted on eight belt's teeth. Measurement is conducted on optical microscope

ZEISS ZKM01-250C. The following values were measured as illustrated in Plate 3.1

a) at the apex of the belt's tooth - 1,

b) at the flank of the belt's tooth - 2 and

c) at the space between belt's teeth - 3.

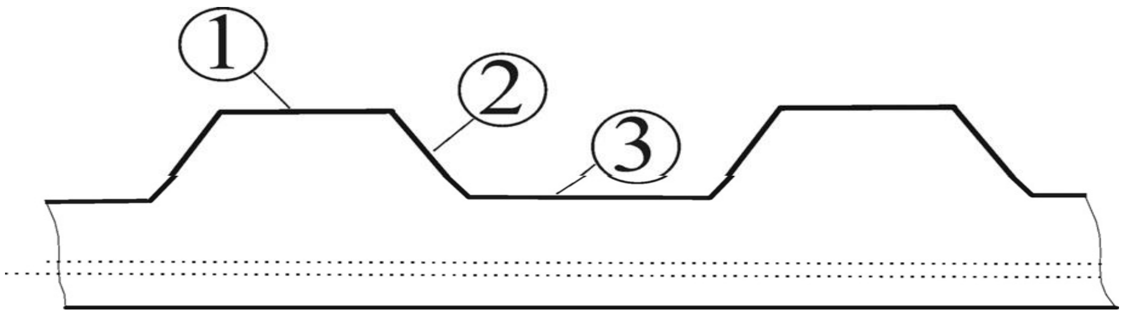


Figure 3.1: Measuring points on the belt for measurement of roughness parameters (B. Stojanovic *et al.*, 2009)

Let

a) Belt's pitch = t

b) Belt's width = b

c) Groove's thickness $h_b = h_s - h_t$

d) Belt's total height = h_s

The following roughness parameters are especially interesting for further analysis: R_a - mean arithmetic deviation of profile from midline of the profile and R_{max} - maximal height of roughness along reference length.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of Experimental Analysis

The variation of the Timing belt Geometry obtained from the Experiment was tabulated as shown in the Table 4.1 below.

Table 4.1: Experimental results of analysis of timing belt geometry of Peugeot 307

ENGINE SPEED (RPM)	OPERATION TIME (Hrs)	PITCH (mm)	WIDTH (mm)	GROOVE THICK.(mm)	TOTAL HIGHT (mm)
0	0	13.46	24.76	2.56	5.92
	0.5	13.475	24.76	2.480	5.92
1000	1	13.480	24.76	2.440	5.91
	2	13.488	24.76	2.390	5.91
	4	13.490	24.76	2.340	5.90
	0.5	13.477	24.76	2.475	5.90
1500	1	13.482	24.76	2.430	5.90
	2	13.492	24.76	2.370	5.90
	4	13.495	24.76	2.310	5.90
	0.5	13.479	24.76	2.470	5.90
2000	1	13.485	24.76	2.400	5.90
	2	13.494	24.76	2.340	5.90
	4	13.496	24.76	2.290	5.90

The graph of timing belt Pitch wear against run time was plotted as shown in Figure 4.1 below.

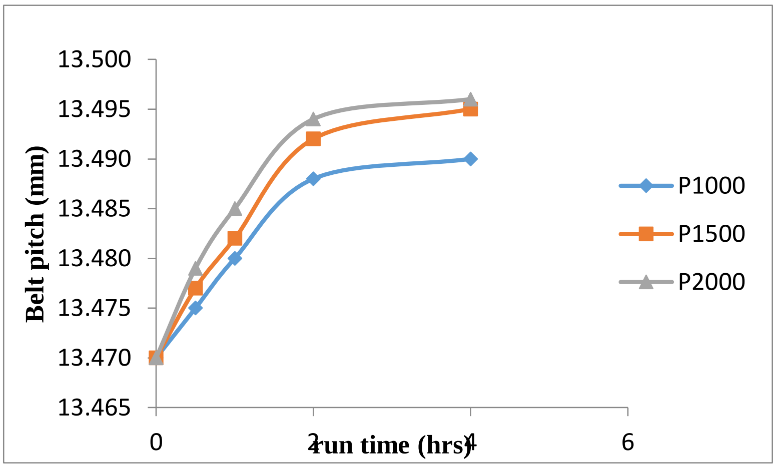


Figure 4.1: Variation of pitch with run time

The Figure 4.2 represents the plotted graph showing the effect of belt Pitch against Engine speed

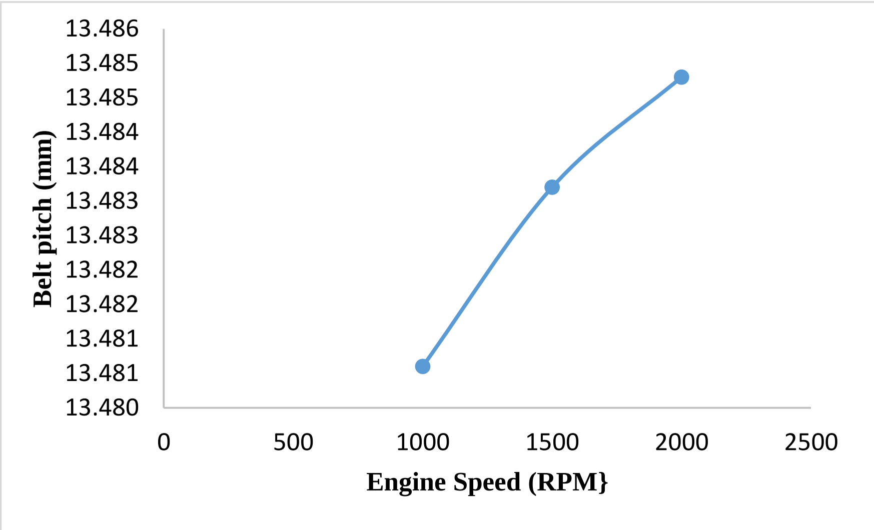


Figure 4.2: Variation of belt Pitch with Engine speed

The graph showing the relationship between belt groove thickness and run time was plotted as shown in Figure 4.3 below.

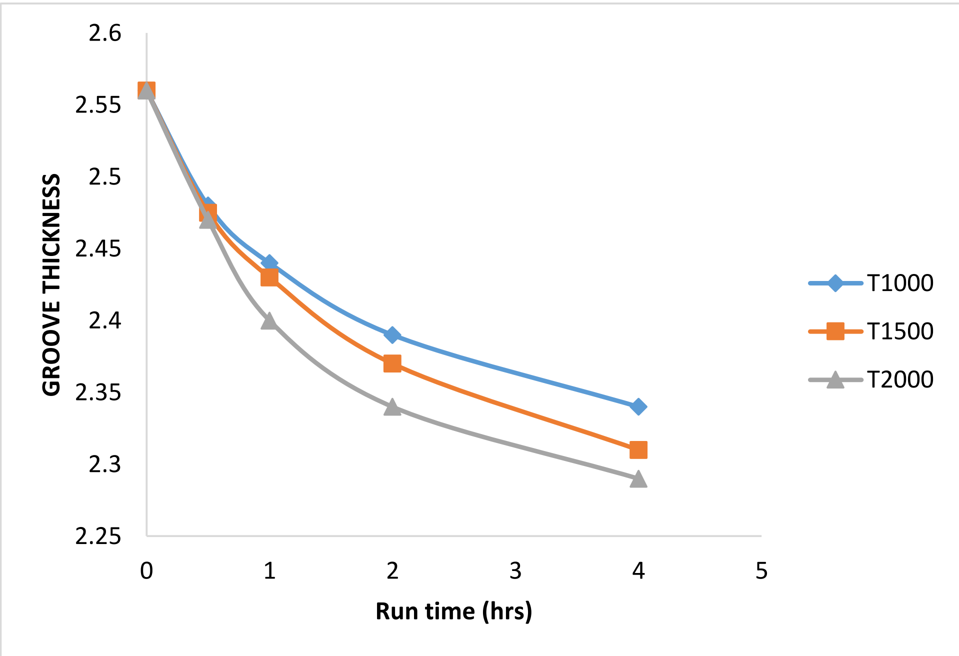


Figure 4.3: Variation of belt groove thickness with run time

The Figure 4.4 represents the plotted graph showing the effect of belt groove thickness against Engine speed

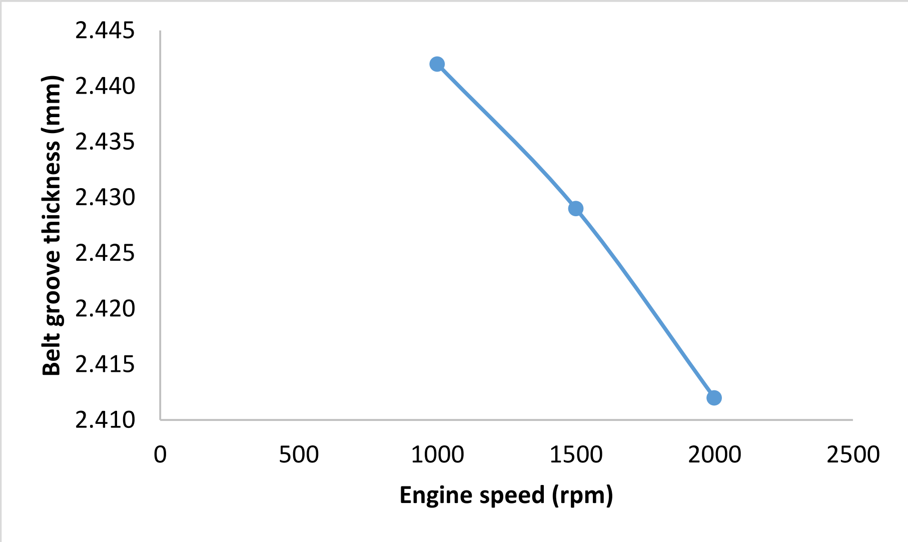


Figure 4.4: Variation of belt groove thickness with Engine speed

4.2 Simulation results

The simulation of the built model is shown on the Figure 4.5 and 4.6.

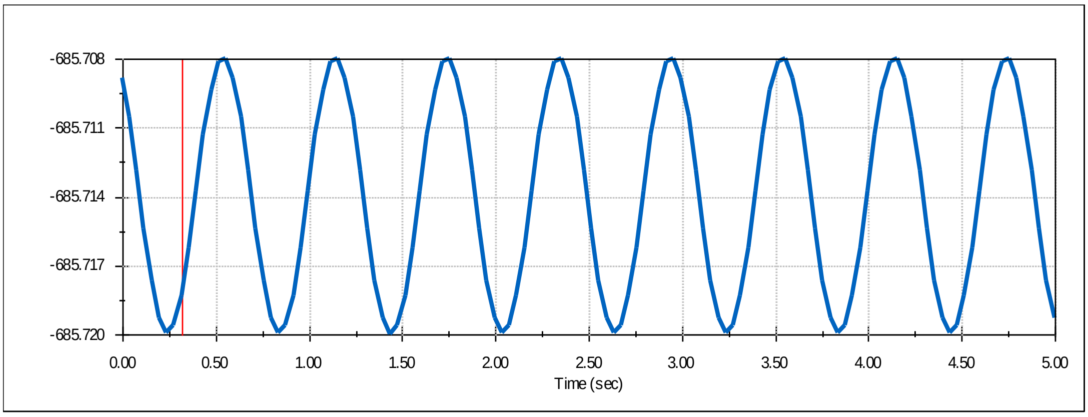


Figure 4.5: The relationship between angular velocity and time.

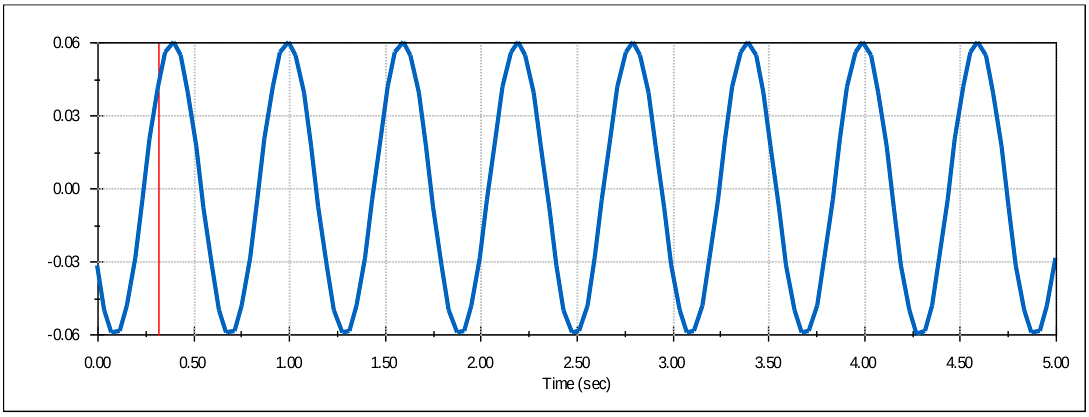


Figure 4.6: The relationship between angular acceleration and time

4.3 Load Distribution in the Belt

Due to the action of the force of pre-tensioning, the tension condition of the belt changes in respect to the tension force. Load distribution in the belt is much more uniformed due to the increase of the force of the pre-tensioning, as illustrated in Figures 4.7 and 4.8.

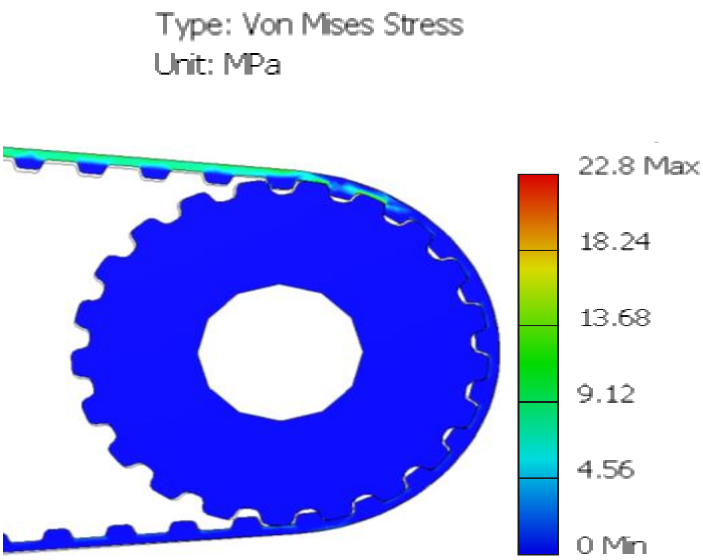


Plate XXVIII: Load distribution at F = 500 N

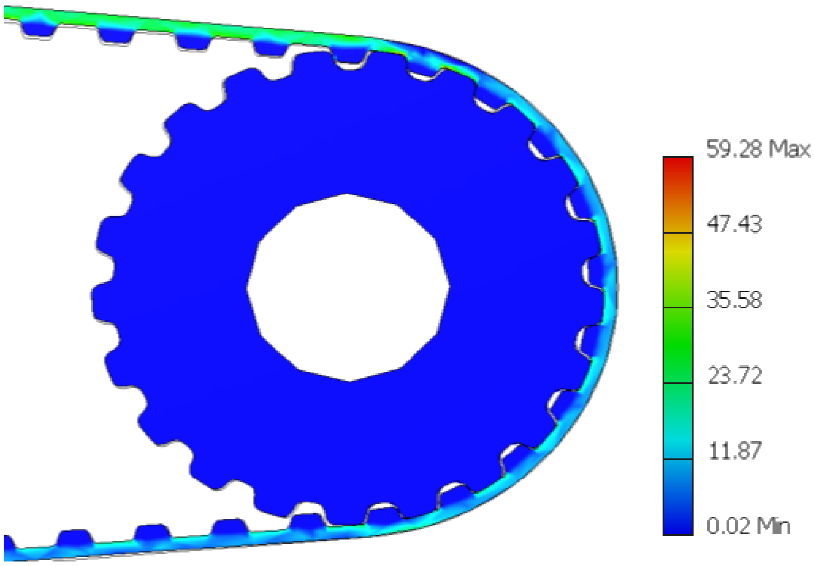


Plate XXVIV: Load distribution at F = 1000 N

4.4 The Impact of Pre-Tensioning Force on Load Distribution

The graph showing the relationship between Von Mises tension and number of tooth of mesh was plotted as shown in Figure 4.9 below.

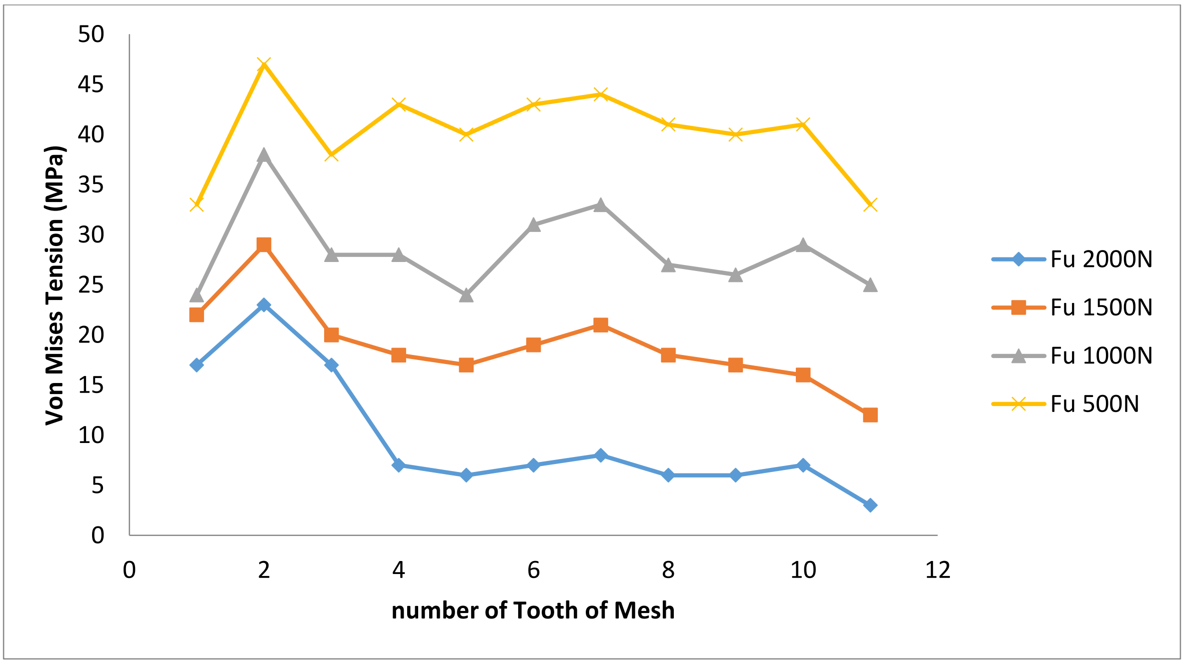


Figure 4.9: Load distribution on teeth in mesh due to the pre-tensioning force

4.5 Discussion of Results

By monitoring the parameters in the period of working out, Figures 4.1 and 4.2 shows that the pitch and the thickness wear were more pronounced between 0-2 hours of operation after which they becomes approximately linear. It was also observed from Figure 4.3 which shows that there is a linear relationship between the engine speed and the belt pitch. Increase in speed will cause the pitch wear to increase accordingly, whereas from Figure 4.4 it shows that increasing the speed reduces the groove thickness. Gained experimental results fully coincide with that of Stojanovic 2011.

The test model was run 5 times and each time the belt cut the sensor automatically stop the electric motor which conform with that of Ucar 2012

The simulation graph shows that the belt reaches the angular speed of 685.708 deg/sec and angular acceleration of 0.06 deg/sec^2 in less than a second and continues to repeat the patter at steady speed.

From the Figure 4.7 and 4.8 it was observed that tension condition of the timing belt along polygonal profile of the driving pulley due to the force of the pre-tensioning was much more convenient at F = 1000 N compared with the case when is F = 500 N . The presence of the force leads to a better meshing of belt teeth and belt pulley, a larger number of teeth participates in the transmission of the torque which leads to more uniform distribution of the load along the belt. The change of tension on the teeth of the belt in mesh due to the pre-tensioning force was presented in Figure 4.9.

From Figure 4.9 it can be shown that with the increasing of the value of pre-tensioning force the tensions on the belt teeth also increase. The results of the analysis due to the presence of the pre-tensioning force explained that the increases and decreases of the tension occur always on the same teeth. The first two teeth in mesh were the most overloaded and the value of the tension decrease as the belt moves from the tractive to free section.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research revealed the effects of run time and speed on the timing belt geometry. Also a test model was developed for experimentation using Peugeot 307 timing belt, crankshaft sprocket, camshaft sprocket, water pump, idler pulley and a tensioner respectively.

The research also revealed that the run time and engine speed affects the belt pitch and the groove thickness, but the pitch was more affected than the belt width and the total belt height.

The model developed stops the engine from running immediately the timing belt failed and shown during test that the belt speed reaches the angular speed of 685.708 deg/sec and angular acceleration of 0.06 deg/sec^2 in less than a second

The analysis of the results shows that the presence of the pre-tensioning force significantly impacts the load distribution in timing belt. The most overloaded were the first three teeth of the belt in tractive section, and on the rest of the teeth the load distribution is more even.

Finally with this research it can be conclude that the lifetime dependency and influenced factors of timing belt drives will help us to provide guidance while occurring on those damages of belts and also the study of various effects on failure analysis steps of common study resulting on a decreasing performance that further lead to help for saving our money and valuable time of maintenance.

5.2 Recommendations

Reliable and long working life of timing belt drives is possible only under certain conditions:

i. Belt drive should be isolated from dirt and chemical solvents.
ii. Belt pulleys and belt tensioners should be manufactured and assembled according to technical documentation.
iii. The belt should be checked at interval of 15,000km for proper tensioning and other defects.
iv. Belt tensioning should be done according to producer’s recommendations and with corresponding devices (tensiometers).
v. Belt drive should be replacement at intervals of 30000 to 50000 miles (50000 to 80000 km)
vi. The Timing belt should not be over run.

REFERENCES

Argentina Press Kit. (2010, November). Retrieved April 2018, from Wayback machine: http://www.psa-peugeot-citroen.com

Aniket, V., & Gujar, A. (2016). Literature review on simulation and analysis of timing belt of an automotive engine. *International journal of Engineering research and application*, 6(8), 17-21.

Auto, Z. (2017). *Auto zone*. Retrieved 2018, from Auto zone: http://www.autozone.com

Autokist. (2009). *Infogramme: ADAC-Pannenstatistik*. Retrieved 2018, from http://http://www.autokiste.de

B. Stojanovic, L. I. (2010). Friction and Wear in Timing Belt Drive. *Tribology in Industry*, 32(3), 33-40.

B. Stojanovic, N. M. (2009). Analysis of Tribological Processes at Timing Belt's Tooth Flank. *Tribology in Industry*, 31(3-4), 53-58.

Callegari, M. a. (2011). Lumped parameter model of timing belt transmissions . *AIMETA'01*.

Dolan, J. A. (1971). *Motor vehicle technology and practical work: parts 1 and 2.* Heinemann Educational Publishers.

Domek, G. (2011). Meshing in gear with timing belts. *International Journal of Engineering and Technology (IJET)*, 3(1), 26-29.

Dudziak, D. G. (Cancun 2008). Mechanics of bending of timing belts with non-straight teeth. *The Tenth Pan American Congress of Applied Mechanics*, X PACAM' 08, 215-218.

Econofix. (n.d.). *Econofix*. Retrieved 2017, from (https://econofix.com).

Gates. (2010, may 12). *Gates 2010 Timing belt installation manual*. Retrieved may 16, 2018, from www.autoserviceworld.com

Gerbert, G. J. (2010). Load distribution in timing belts. *ASME.J.Mesh.Design*, 100(2), 208-215.

Goodyear. (2010). *Good year introduces Timing belt tools*. Retrieved from www.autoserviceworld.com

Johannesson, T. a. (2002). Dinamic Loading of Synchronous Belts. *ASME, Mechanical Design*, 124, 79-85.

Karolev, N. a. (1995). Load distribution of timing belt drives transmitting variable torques . *Mech.Mach.Theory*, 30(4), 553-567.

Krumi, R. S., & Gupta, J. K. (2008). *A Textbook of Machine Design* . New Delhi: Euroshia.

Milanović, I. (2010). Calculation and analysis of timing belt drives. *Master thesis, Kragujevac*.

Milanović, I. S. (2011). Influence of torque variation on timing belt drive's load distribution. *The 7th International scientific conference IRMES*, 559-562.

Norbye, J. p. (1984). Expanding on Excellence. *The 5-Series and 3-Series". BMW - Bavaria's Driving Machines. Skokie, IL, USA: Publications International*, 192. ISBN 0-517-42464-9.

Ritch, O. (2014). *Small bore big pull*. Retrieved from https:web.archive.org

Siegel, i. (2007, April 5). *Rattling noise could be from worn timing belt*. Retrieved from Chicago sun times: https://web.archive.org

Simmons, K. (2009, February). *Timing to win ignition timing for maximum performance*. Retrieved from Circle track magazine: www.hotrod.com

Stojanovic, B., Ivanovic, L., & Blagojevic, M. (2011). Failure Analysis of the timing belt drives. *International Conference on Tribology in Serbian Tribology Society*, 21, 210-215.

Stojanovic, B., Tanasijevic, N., & Miloradovic, N. (2009). Trobomechanical systems in Timing belt drives. *Journal of balkan tribological association*, 15(4), 465-473.

T. H. C. Childs, K. W. (1997). The meshing of timing belt teeth in pulley grooves. *Proceedings of the Institute of mechanical engineers; Part D: Journal of Automible Engineering*, 211(3), 205-218.

Temple, S. (2004). *Behold your timing belt: keeping the camshaft and crankshaft in sync*. Retrieved from Know how advance auto parts: https://web.archive.org

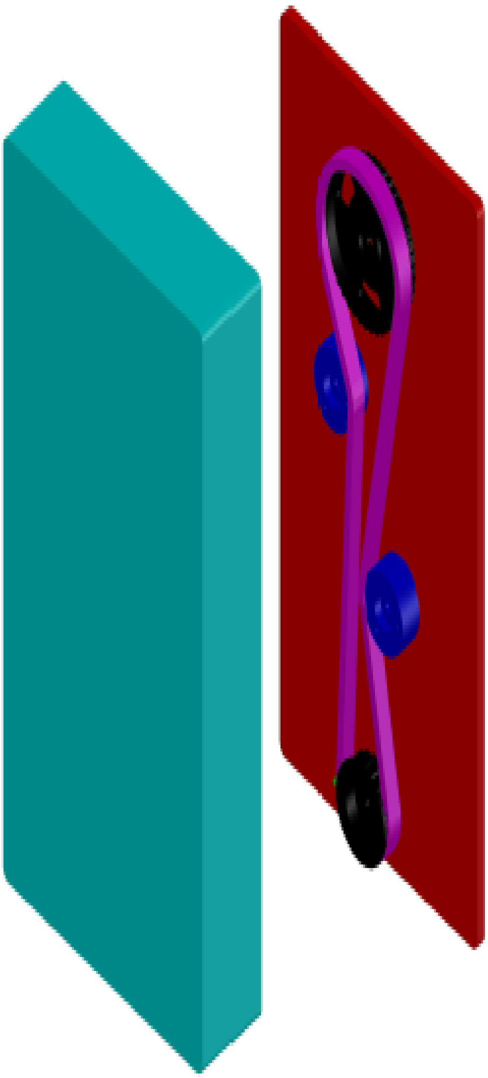
Kost F. (2014). *Basic principles of vehicle dynamics. In: Reif K. (eds) Fundamentals of Automotive and Engine Technology*. Bosch Professional Automotive Information. Springer Vieweg, Wiesbaden. Retrieved from https://link.springer.com/chapter/10.1007%2F978-3-658-03972-1_10#citeas

Mastinu, G. (2014). Road and Off-Road Vehicle System Dynamics Handbook. Ploechl, Manfred, eds. CRC Press. P. 1613. ISBN 9780849333224. Retrieved 16 March 2014.

Meier, U. (2012). "1 Non Finito: challenges in rehabilitation". In Fardis, Michael N. Innovative Materials and Techniques in Concrete Construction: ACES Workshop. *Springer. 12.* ISBN 9789400719965. Retrieved 16 March 2014.

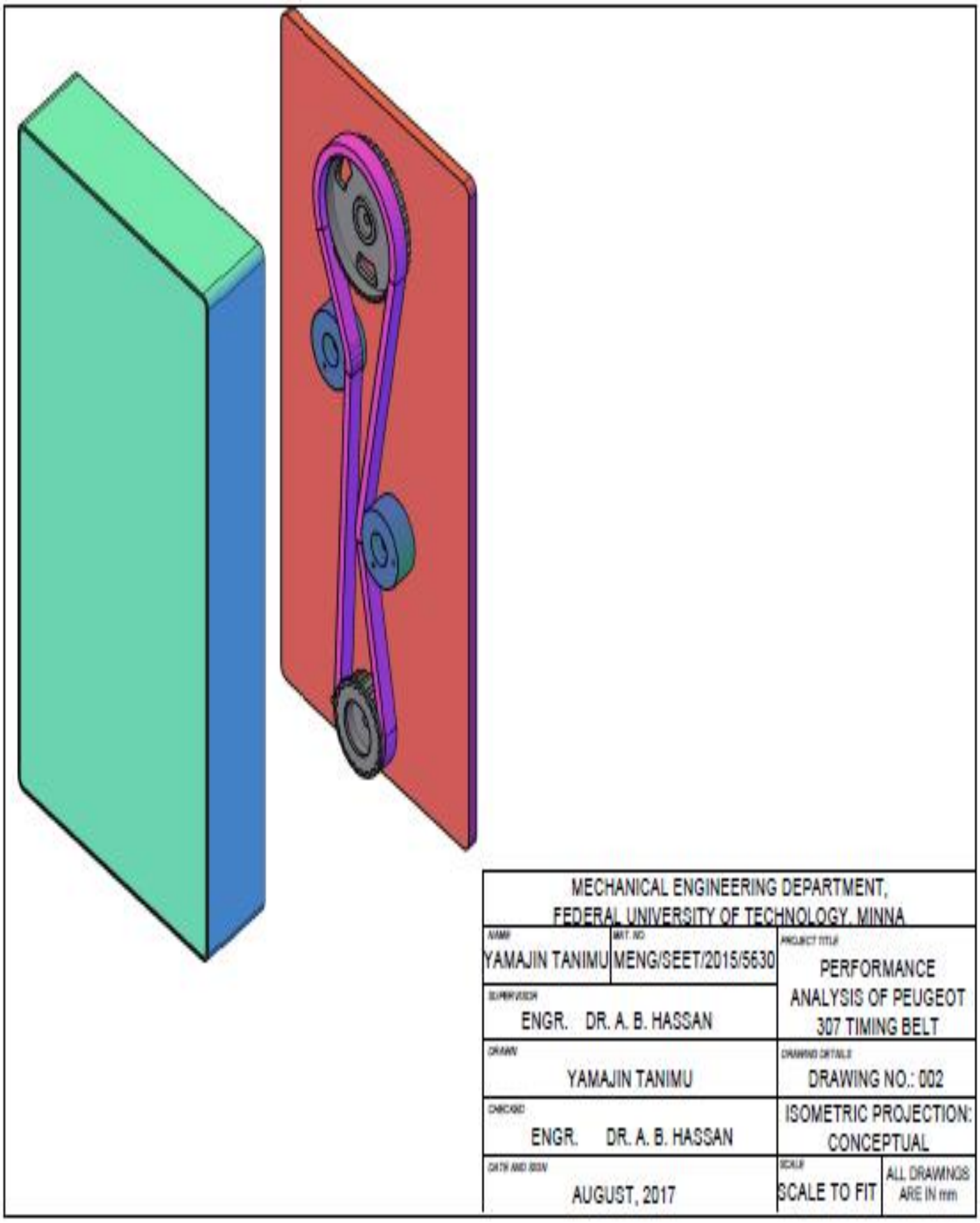
Simran, S. (2013). *What are Proximity Sensors, How They Work and Types?* Retrieved from http://thegadgetsquare.com/1334/what-are-proximity-sensors-types-and-how-it-works/

APPENDIX A

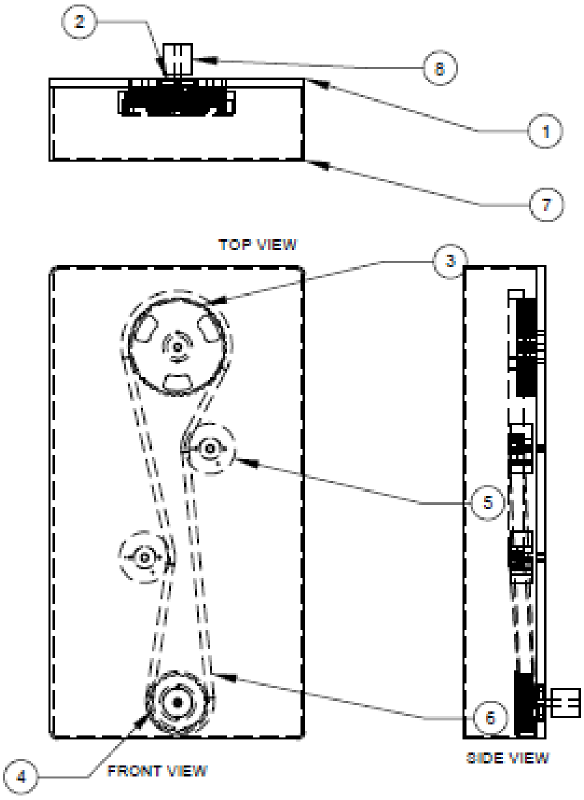


MECHANICAL ENGINEERING DEPARTMENT, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA			
NAME: YAMAJIN TANIMU	MAT. NO.: MENG/SEET/2015/5630	PROJECT TITLE: PERFORMANCE ANALYSIS OF PEUGEOT 307 TIMING BELT	
SUPERVISOR: ENGR. DR. A. B. HASSAN			
DRAWN: YAMAJIN TANIMU		DRAWING DETAILS: DRAWING NO.: 001	
CHECKED: ENGR. DR. A. B. HASSAN		ISOMETRIC PROJECTION	
DATE AND SIGN: AUGUST, 2017		SCALE: SCALE TO FIT	ALL DRAWINGS ARE IN mm

APPENDIX B


MECHANICAL ENGINEERING DEPARTMENT,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
YAMAJIN TANIMU
MENG/SEET/2015/5630
PERFORMANCE ANALYSIS OF PEUGEOT 307 TIMING BELT
ENGR. DR. A. B. HASSAN
YAMAJIN TANIMU
DRAWING NO.: 002
ENGR. DR. A. B. HASSAN
ISOMETRIC PROJECTION: CONCEPTUAL
AUGUST, 2017
SCALE TO FIT
ALL DRAWINGS ARE IN mm

APPENDIX C



ITEM NO.	PART NUMBER	QTY.
1.	BOARD	1
2.	PULLEY HOLDER	4
3.	BIGGER PULLEY	1
4.	SMALLER PULLEY	1
5.	TENSIONER	2
6.	BELT	1
7.	COVER	1
8.	MOTOR	1.

MECHANICAL ENGINEERING DEPARTMENT,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

YAMAJIN TANIMU | MENG/SEET/2015/5630

PERFORMANCE ANALYSIS OF PEUGEOT 307 TIMING BELT

ENGR. DR. A. B. HASSAN

YAMAJIN TANIMU

DRAWING NO.: 003

ORTHOGRAPHIC PROJECTION

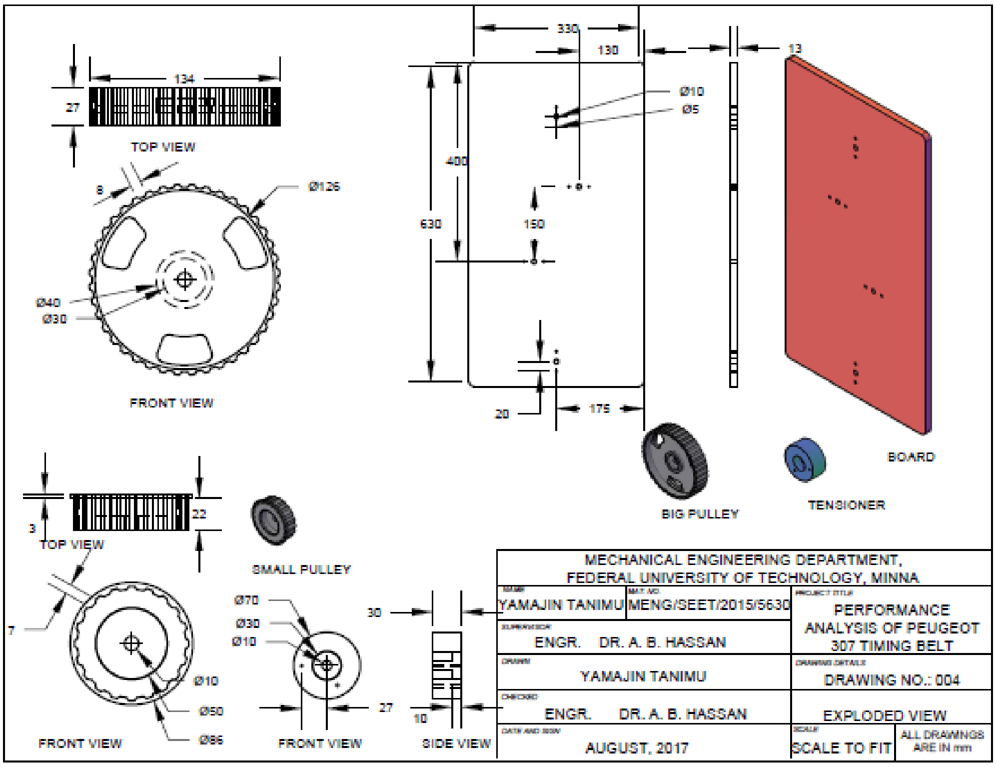
ENGR. DR. A. B. HASSAN

AUGUST, 2017

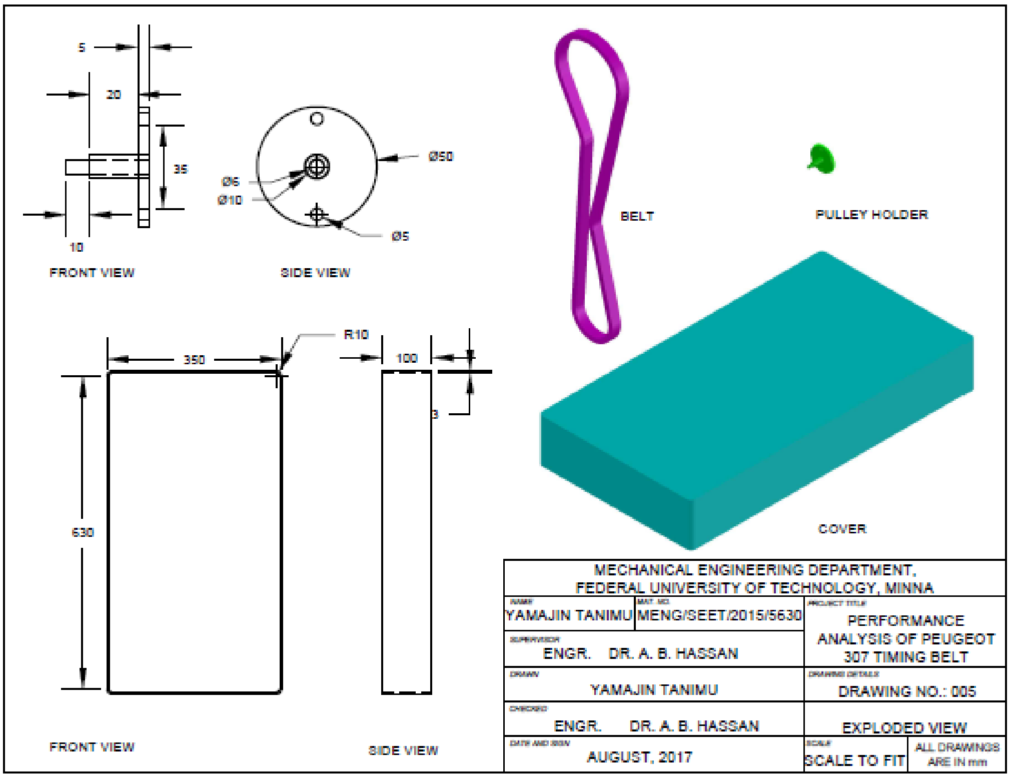
SCALE TO FIT

ALL DRAWINGS ARE IN mm

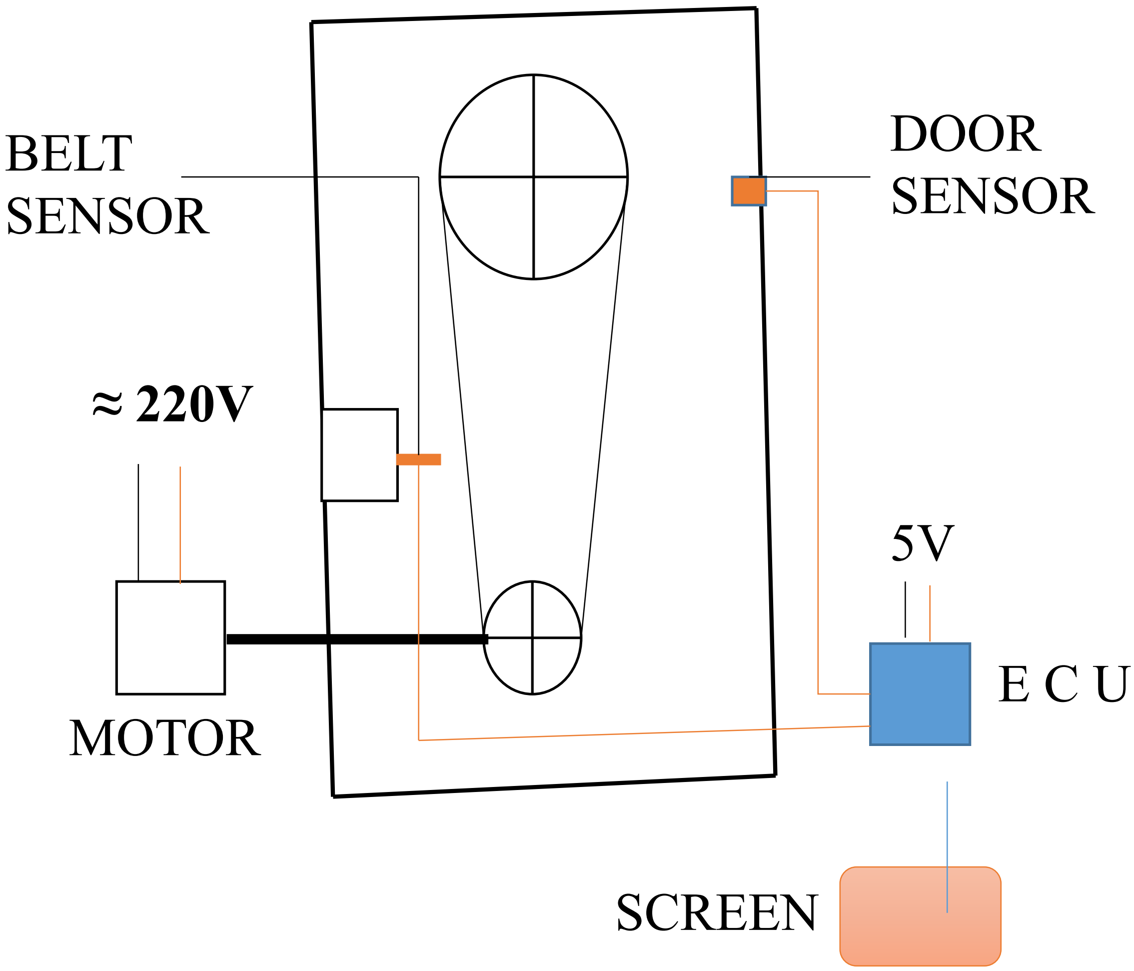
APPENDIX D



APPENDIX E



APPENDIX F



SCHEMATIC DIAGRAM