MACHINE DESIGN – 1
MINOR REPORT

Bachelor of Technology

in

Mechanical Engineering

by

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Declaration

I declare that this written submission represents my ideas in my own words and where others' idea or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honestly and integrity and have not misrepresented of fabricated or falsified any idea / data / fact / source in my submission. I understand that any violation of the above will be cause for disciplinary action by the PANDIT DEENDAYAL ENERGY UNIVERSITY.

(Signature of the Student)

(Kush Patel)

DATE-

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❖ Chapter 1: INTRODUCTION

The belt drives are usually used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. They are flexible in nature and are intermediate between the driving and the driven shaft. the rotary motion of the driving shaft is first converted into translatory motion of the belt or chain and then again converted into rotary motion of the driven shaft. Thus, a flexible element is superimposed between the driving and driven elements.

The amount of power transmitted depends upon the following factors:

- The velocity of the belt.
- The tension under which the belt is placed on the pulleys.
- The arc of contact between the belt and the smaller pulley.
- The conditions under which the belt is used.

ADVANTAGES

- Flexible drives transmit power over a comparatively long distance due to an intermediate link between driving and driven shafts.
- Since the intermediate link is long and flexible, it absorbs shock loads and damps vibrations.
- Flexible drives provide considerable flexibility in the location of the driving and driven shafts. The tolerances on the center distance are not critical as compared with a gear drive.
- Flexible drives are cheap compared to gear drives. Their initial and maintenance costs are low.

DISADVANTAGES

- They occupy more space.
- The velocity ratio is relatively small.
- In general, the velocity ratio is not constant.

❖ Chapter 2: Literature Review

➢ **At least five practical applications with proper photographs and explanation?**

- **Marine Diesel Engine**

The belt drive is used in to transfer power in automobile sector and so is used in components like marine engine. As it can be easily removed and replaced it forms an important component in marine diesel engine. They transfer rotational power from crankshaft to the pulleys that drive the engine coolant circulating pump.

- **Conveyor System**

A belt drive is extensively used in conveyor system in handling and moving material from one place to another. They are used to easily transport heavy goods from one place to another. Conveyors are mostly found in industries and airports to transfer goods from one location to another.

- **Milling machine**

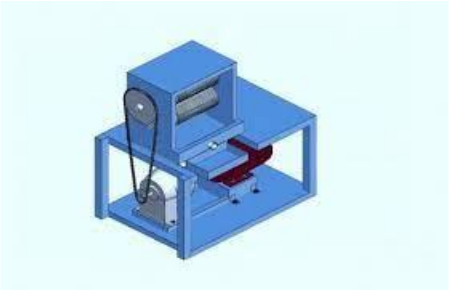
A belt drive is used in a milling machine to transfer power from one part to another.

- **Agricultural Machinery**

Nowadays there is a major use of belt drives in agricultural machinery as it makes the job easy. Chain drive is used to cut the vegetation and yield the crop while the belt drive carries it to the storage tank and if water is introduced in between, it can also clean the crop. This technology is used in developed countries and mostly for underground grown vegetables.

- **Electric Sugarcane juice and Machine**

Belt drive is used in Electric sugarcane juice machine and ice gola machine to extract sugarcane juice and break ice. The engine works on electricity and a belt is attached to the shaft which rotates at high rpm which is used to compress sugarcane or crush ice.



➢ Leading industries that manufacture belt drives

- Gates
- Optibelt
- ContiTech
- Dayco
- Fenner

➢ Indian standards used for design

ISO 22:1991 Flat transmission belts and corresponding pulleys
ISO 155:2019 Pulleys — Limiting values for adjustment of centers
ISO 254:2011 Pulleys — Quality, finish and balance
ISO 255:1990 Pulleys for V-belts (system based on datum width) — Geometrical inspection of grooves
ISO 1081:2013 V-belts and V-ribbed belts, and corresponding grooved pulleys
ISO 1604:1989 Endless wide V-belts for industrial speed-changers and groove profiles for corresponding pulleys
ISO 1813:2014 V-ribbed belts, joined V-belts and V-belts including wide section belts and hexagonal belts — Electrical conductivity of antistatic belts
ISO 4183:1995 Classical and narrow V-belts — Grooved pulleys (system based on datum width)
ISO 4184:1992 Classical and narrow V-belts — Lengths in datum system
ISO 5288:2017 Synchronous belt drives
ISO 5290:2001Grooved pulleys for joined narrow V-belts — Groove sections 9N/J, 15N/J and 25N/J (effective system)
ISO 5291:2011 Grooved pulleys for joined classical V-belts — Groove sections AJ, BJ, CJ and DJ (effective system)
ISO 5295:2017 Synchronous belts — Calculation of power rating and drive center distance

ISO 8370-1:1993 Dynamic test to determine pitch zone location — Part 1: V-belts
ISO 8370-2:1993 Dynamic test to determine pitch zone location — Part 2: V-ribbed belts
ISO 8419:2003 Narrow V-belts — Sections 9N/J, 15N/J and 25N/J (lengths in the effective system)
ISO 9563:2015 Electrical conductivity of antistatic endless synchronous belts
ISO 9608:2022 Uniformity of belts — Test method for determination of center distance variation
ISO 9980:2012 Grooved pulleys for V-belts (system based on effective width) — Geometrical inspection of grooves
ISO 9982:2021 Pulleys and V-ribbed belts for industrial
ISO 11749:2014 V-ribbed belts for the automotive industry — Fatigue test
ISO 12046:2012 Automotive belts — Determination of physical properties
ISO 13050:2022 Metric pitch, curvilinear profile systems G, H, R and S, belts and pulleys
ISO 17396:2017 Metric pitch — Tooth profiles T and AT endless and open-ended belts and pulleys
ISO 19347:2015 Synchronous belt drives — Imperial pitch trapezoidal profile system — Belts and pulleys
ISO 21342:2019 Synchronous belt drives — Automotive belts and pulleys

➢ Materials

- Leather belt
  One of the most significant forms of belts, leather belts were initially discovered in Egypt. These belts are frequently encountered in daily life.
  When compared to comparable belts made of cotton or other recycled materials, leather belts are determined to be more expensive. One layer of leather is joined to another layer to strengthen it and increase the thickness of the belt in order to make leather belts sturdy.

- Rubber belt
  A rubber belt is referred to as the fabric-based belt that is frequently utilised in sawmills, paper mills, etc.

- Cotton or Fabric belt
  Cotton or fabric belt is referred to as that type which is mostly used in the farm machinery and belt conveyor. This type of belt is cheaper and also best suited for warm climates and a damp atmosphere.

- Plastic belt
  Plastic belts are the ones which are made up of plastic sheets and rubber layers. The main advantage of a plastic belt is that it can be designed in almost any size which depends on the site requirement.

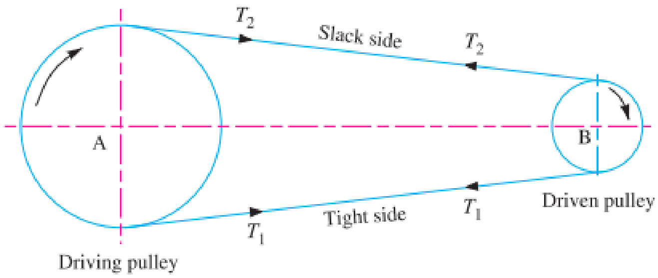
- Balata belt
  Balata belts are referred to as those belts which seem similar to the rubber type belts but are found to be stronger than them. The balata gum is used here to stick the belt properly.

  This type of belt is found to be waterproof and has a high resistance to acidic, alkaline material so this is mostly used for food packaging conveyor. This is not meant for high temperatures as the balata becomes sticky gum at a higher temperature.

❖ Chapter 3: Mathematical and Analytical Model

➢ CALCULATIONS

- **Power transmission to the belt**



- **Forces acting on the belt**

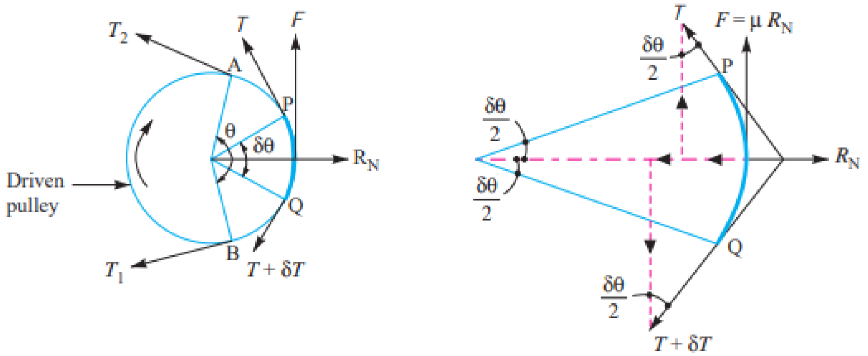
Let T_1 = Tension in the belt on the tight side,

T_2 = Tension in the belt on the slack side, and

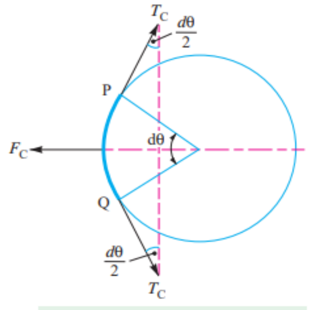
θ = Angle of contact in radians (*i.e.* angle subtended by the arc AB, along which the belt touches the pulley, at the centre).

Now consider a small portion of the belt PQ, subtending an angle $\delta\theta$ at the centre of the pulley as shown in Fig. 18.16. The belt PQ is in equilibrium under the following forces:

1. Tension T in the belt at P,
2. Tension $(T + \delta T)$ in the belt at Q,
3. Normal reaction R_N, and
4. Frictional force $F = \mu \times R_N$, where μ is the coefficient of friction between the belt and pulley.



- **Centrifugal tension**



➢ Design constraints

- Service factor

  Service factor is a multiplier that is applied to the operating hp to determine a conservative minimum hp rating for belting. Service factors were formerly obtained from charts covering load characteristics such as starting torque, cyclic variation of the driven load, expected hours of use per day, and so forth. Most computer programs assist in the selection of the proper service factor designation.

  Limits:

  - Synchronous belt drives require higher service factors than V-belt drives.
  - Service factors that are higher than recommended do not increase belt life unless belt tension is kept at lower than what is normally specified for that belt.
  - Excessive service factors may contribute to excessive bearing loads, because tension applied relates to belt capacity

- Horsepower

  Motor nameplate horsepower is normally referenced when sizing belts. However, the actual horsepower required by the driven device may also be used.

- Driver shaft diameter

  Most programs insert the correct shaft diameter according to National Electrical Manufacturers Association (NEMA) standard publication MG 1 if requested and if within the specified horsepower range. Otherwise, you should enter this dimension if known.

  Limits:

  - Short shaft (TS) motors are designed for direct coupled use only and should not be used with a belt drive.
  - There are two frame options for motors with 125 hp at 1,750-rpm, so be sure to verify the shaft diameter.

- Driven rpm desired

  The computer program selects drives with driven speeds within some percentage of the desired rpm. This range can be adjusted in most programs.

- Driven shaft diameter

  Enter this diameter if known, but this is an optional entry on most programs.

- Centre distance desired

  Centre distance should also be entered if known. Some programs request both minimum and maximum values, but most programs default to some nominal centre distance if no value is entered.

- Driving rpm

  Use full-load rpm ratings of the driver. The driven speed calculations are only as accurate as the input speed entered.

➢ Factor of safety

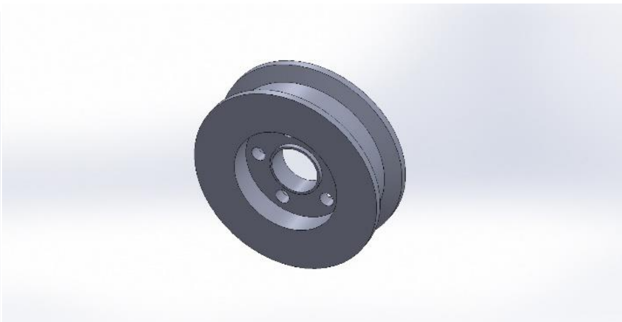
Belt section	*Pitch width W_p (mm)*	*Nominal top width W(mm)*	*Nominal Height T (mm)*	*Recommended Minimum pitch diameter of pulley (mm)*	*Permissible Minimum pitch diameter of pulley (mm)*
Z	8.5	10	6	85	50
A	11	13	8	125	75
B	14	17	11	200	125
C	19	22	14	315	200
D	27	32	19	500	355
E	32	38	23	630	500

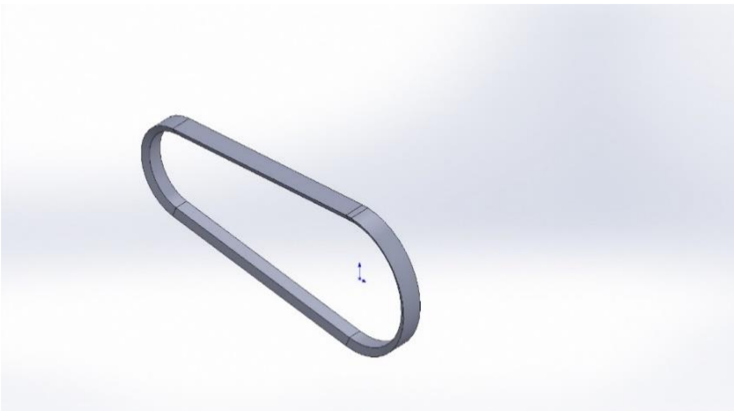
Table 13.15 *Correction factors according to service (F_a)*

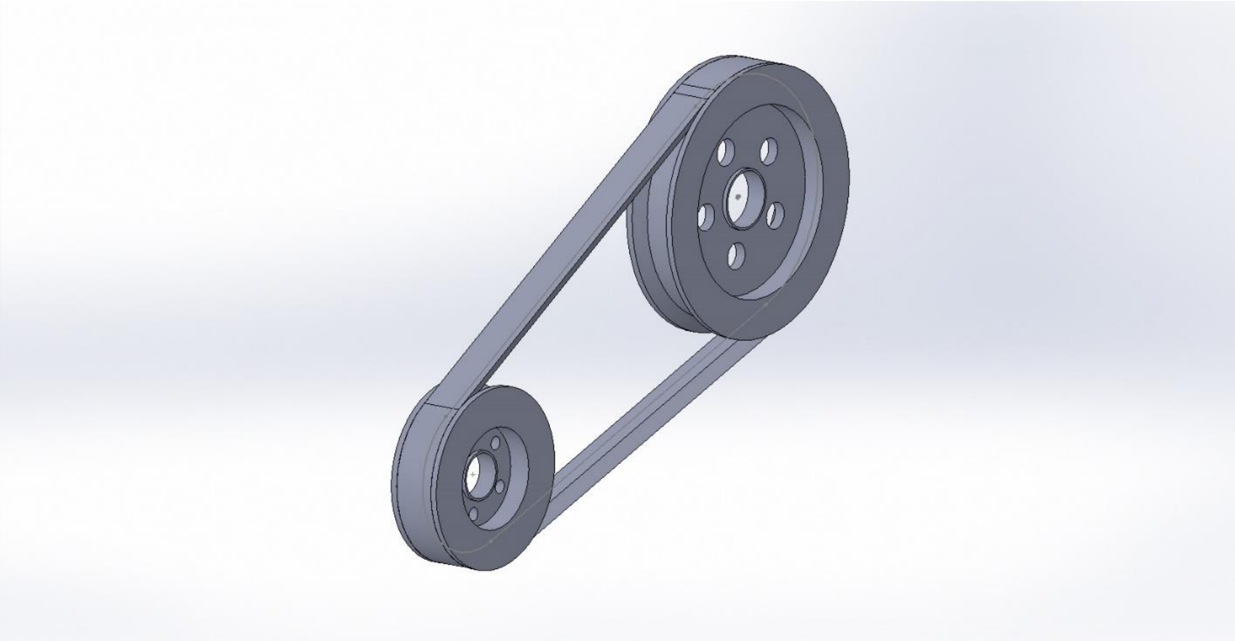
Service	*Type of driven Machine*	*Type of driving units*					
		AC Motor: normal torque, squirrel cage, synchronous and split phase *DC Motor*: shunt wound—multi cylinder IC engine over 600 rpm			*AC Motor*: high torque, induction, single phase *DC Motor*: series and compound wound—*single cylinder IC engine*, Multi cylinder IC engine under 600 rpm—line shaft, *clutches and brakes*		
		Operational hours per day (h)			Operational hours per day (h)		
		0–10	10–16	16–24	0–10	10–16	16–24
Light duty	Agitator, blower, exhauster, centrifugal pumps, compressor and fans up to 7.5 kW and light duty conveyor	1.0	1.1	1.2	1.1	1.2	1.3
Medium duty	Belt conveyor, fans over 7.5 kW, generator, line shaft, machine tools, presses, positive displacement pumps and vibrating screen	1.1	1.2	1.3	1.2	1.3	1.4
Heavy duty	Bucket elevator, hammer mill, piston pump, saw mill, exciter and wood working machinery	1.2	1.3	1.4	1.4	1.5	1.6
Extra-heavy duty	Crusher, mill and hoist	1.3	1.4	1.5	1.5	1.6	1.8

➢ Ergonomically Designed

As man-machine interaction is very less in belt drive so ergonomics doesn't play a significant role in it.







➢ Complexity and Challenges in design

- The first procedure in selection of belt is the material. for a flat v-belt drive we generally use oak tanned/mineral tanned leather.
- The next part is selection of material for pulley. we generally use cast iron because it has excellent damping property.
- The next step is designing with keeping the constrains in mind like the service factor which is generally 1.2
  - The design power is calculated with P= PxC
  - Design stress is usually 2.06 MN/m^2
- The next part is calculating the diameter of motor pulley

$$d= (525\text{-}630)\sqrt[3]{\frac{P(KW)}{\omega_{max}}} = (525\text{-}630)\sqrt[3]{\frac{P(KW)}{2\pi n_{max}}} \text{ where } n_{max} = \text{speed in rps}$$

- Diameter of driven pulley is designed keeping creep factor of the belt in mind
- The speed of pulley is calculated

$$v=\frac{\pi D_1 N_1 (1-\epsilon)}{60} \text{ ,where } D_1 \leftarrow \text{diameter of driver },N_1 \leftarrow \text{rpm of driver}$$

- Centre distance is then calculated
  - C= (1.5-2) (D+d)
- Coefficient of friction is calculated
  - $$\mu = 0.54 - \frac{0.712}{2.542+v}$$
- Then the length of belt and angle od contact is calculated which varies from type to type of belt.
- Then the width of the belt is finalized and tension is calculated
- Once the tension is calculated, the belt is tested and ready for application.

➢ Cost

- Materials: The type of material used for the pulleys, the belt, and other components will affect the cost. For example, using a high-quality material such as stainless steel will be more expensive than using a cheaper material like aluminum.
- Design: The complexity of the design and the number of components involved in the belt drive will also impact the cost.
- Manufacturing process: The method used to manufacture the belt drive and the location of the manufacturer will also affect the cost.
- Quantity: The cost of making a belt drive decreases as the quantity produced increases.

It is difficult to provide an exact cost for making a belt drive without knowing the specific requirements and details of the belt drive. However, a rough estimate of the cost can be obtained by getting quotes from manufacturers or suppliers.

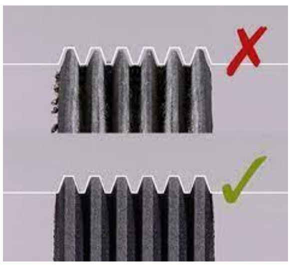
➢ Breakage of components with practical photographs

- **RAPID SIDEWALL WEAR**

Although side wall wear is inevitable over time, rapid sidewall wear can be a sign of a bigger problem, as most commonly it can be attributed to worn or damaged pulleys. However, there are many other possible influencing factors such as: using belts in extreme heat, excessive oil, grease, moisture and other generally abrasive environments can also cause this type of wear.

- **WORN COVER ON BACK**

Most commonly, back wear is a direct cause of the belt being forced or pried on to the pulley or that there is some misplaced slack within the belt which is causing damage by vibrating against the idler during operation. Although, on some occasions defective or worn backside idlers can contribute to worn backside covers, although this is less common.



- **BELT SOFT, SWOLLEN**

Excessive exposure to oil or grease can be a recipe for disaster for some v-belts as these products can cause belts to soften and become swollen, and thus no longer fitting properly into the pulley groove. This sort of problem could also be similarly attributed to the use of belt dressing.

- **BELT SLIPS, SQUEALS (SPIN BURN)**

Spin burn can be cause by worn or damaged pulleys, and incorrect tensioning, which can wreak havoc on your belts causing damage and ultimately, premature failure. This can also be less commonly caused by using the wrong belt cross-section or type, excessive oil, excessive grease or moisture and insufficient wrap on a small pulley.

- **SPLIT BELT COVER**

There's a lot to be said about the damage that can be caused from forcing a belt onto a pulley or running your v-belts with the incorrect tension, as this is the most common cause for many types of belt damage, including cover splits.

- **UNDERSIDE CRACKED**

Cracking in belts can cause serious issues, particularly if they are left untreated as they can affect drive efficiency and eventually cause belt failure. Cracks commonly begin to appear on belts that are being exposed to excessive heat. Although it cannot always be exclusively attributed to this, as pulleys and backside idlers that are too small or misaligned can also cause this cracking.

- **MISSING COGS**

Missing cogs can cause belts to slip and fall, when it is discovered, there are teeth missing, the belt should be changed immediately. The most common reasons your belt could be missing a cog are excessive heat, the pulleys are too small or misaligned. It can also be caused by improper or prolonged storage of belts.

- **CRACKED BUSHINGS**

Having cracked bushings means your drive is in dangerous territory, if the damage becomes too severe, your pulleys may not be attached securely to the shaft. Bushings can become cracked due to excessive tension from the drive or using worn or damaged pulleys.

➢ Failure Criteria to be considered.

- Improper operating tension
- Pulley misalignment due to slippage
- Worn occurs in pulley due to constant load
- Temperature wear (due to high temperature)
- Chemical contamination due to fluids
- Insertion of foreign objects in the belt drive assembly
- Slippage in belt
- Fatigue in belt
- Worn belt and pulley
- Normal wear rate
- Rapid belt deterioration

❖ Chapter 4: Modelling and coding

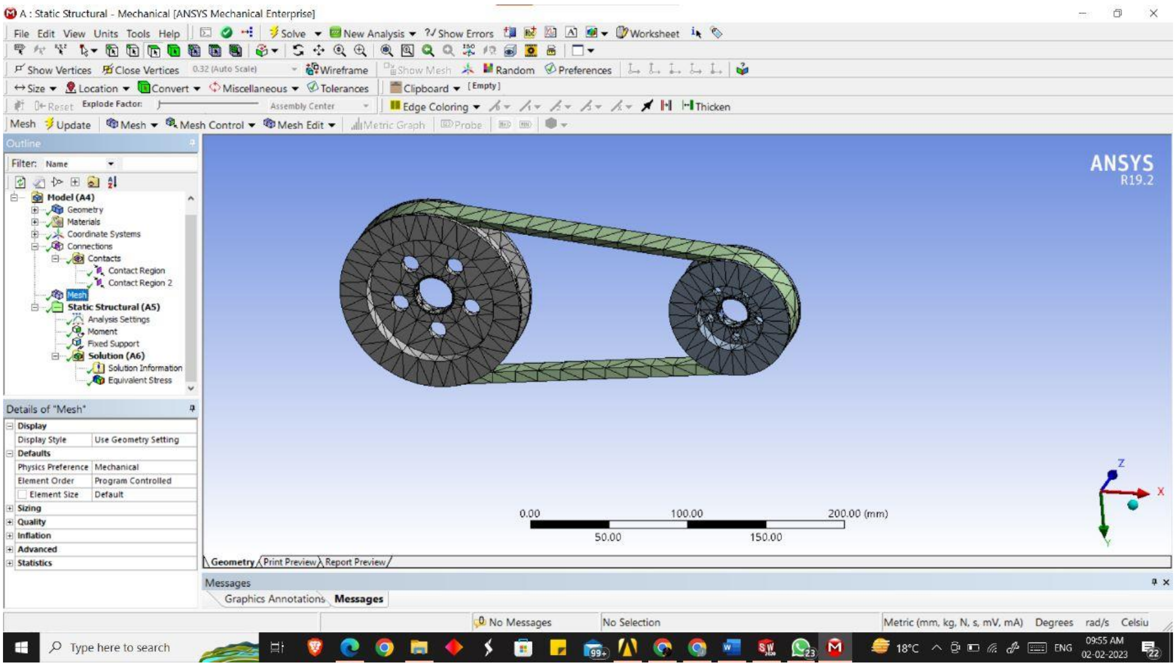
Here we first define the variables such as diameters of the pulleys, tension in the belt,and the speed of the belt. Then we use these variables to calculate the power transmitted in the belt drive using the formula for power transmission in a belt drive.

```
% Define the variables
diameter_pulley_1 = 0.3; % m
diameter_pulley_2 = 0.15; % m
belt_tension = 100; % N
belt_speed = 10; % m/s
power_transmitted = 0; % W

% Calculate the power transmitted
power_transmitted = (0.5 * belt_tension * (diameter_pulley_1 + diameter_pulley_2) *
belt_speed) / (diameter_pulley_2 / diameter_pulley_1);

% Display the result
fprintf('The power transmitted by the belt drive is: %f W\n', power_transmitted);
```

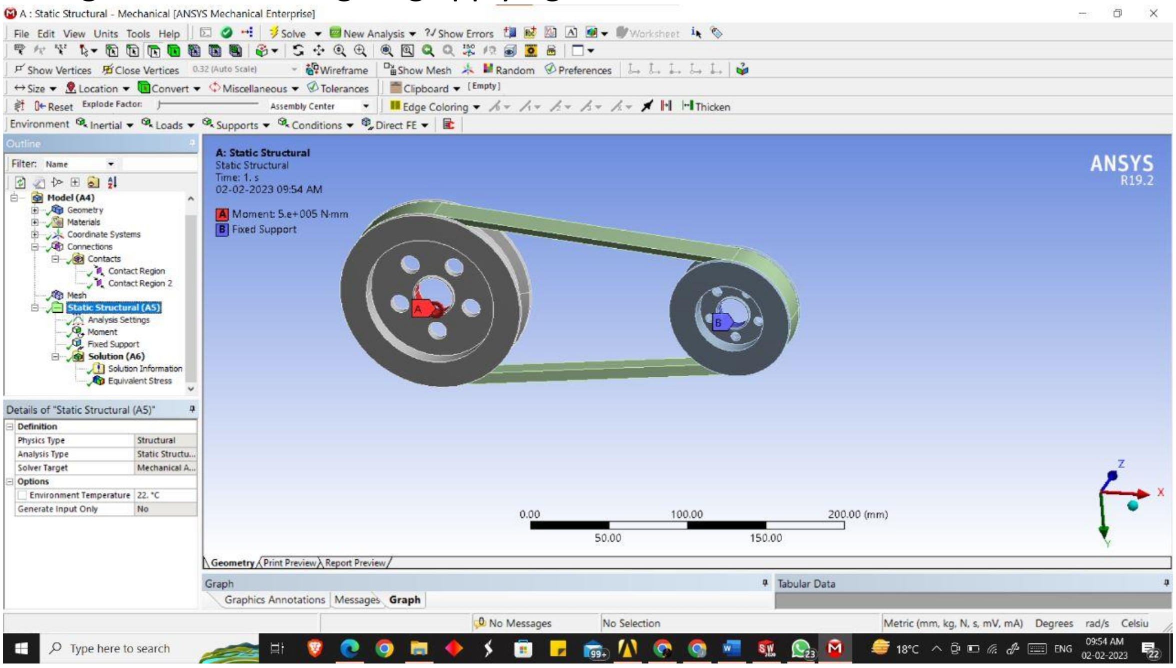
❖ Chapter 5: Static analysis and results

➢ **Software Based Analysis like FEA, Mesh Free, Boundary Element methods etc. with photographs.**

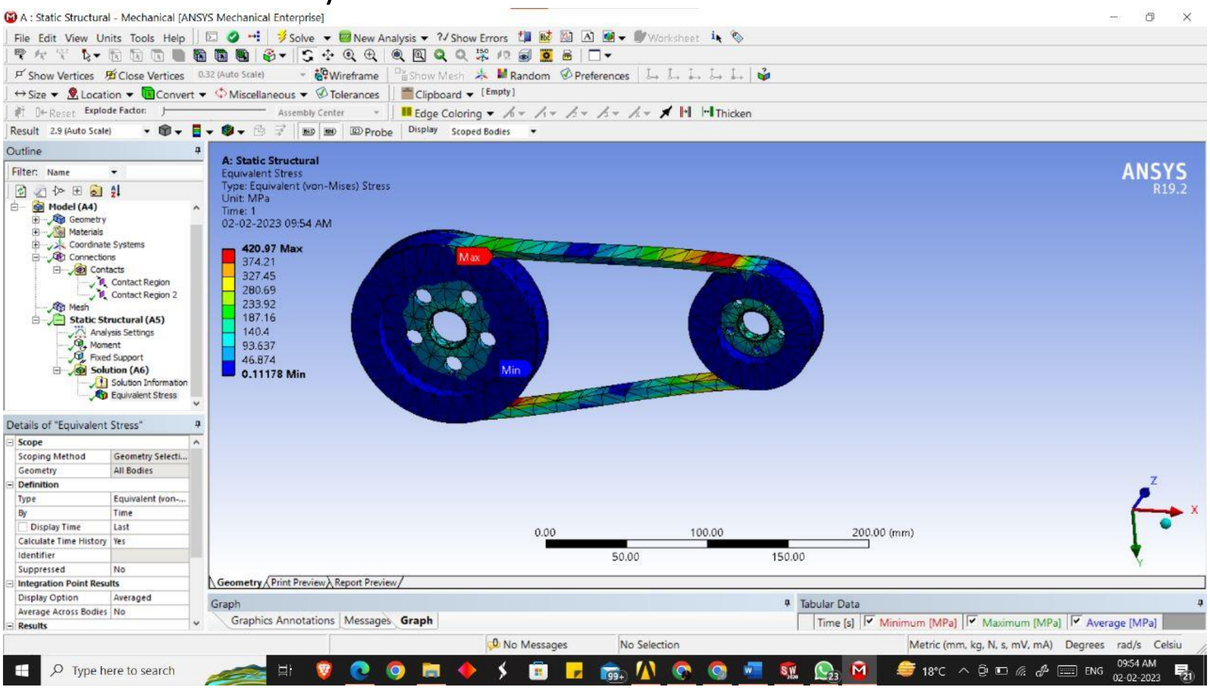
Mesh selection in Belt Drive.



Giving constrains and giving applying moment in Belt Drive.



Static Structural Analysis



❖ Chapter 6: Conclusion

➢ Old and Recent applications with photographs and explanation

Belt drives has a wide use in many practical and day to day life equipment. It is widely used in power transmission devices to transfer torque and power. It has its main application in Engines and Conveyor systems. These days belt drive is also widely used in Milling industry.
Belt drive is a traditional device and still has a use in today's era but there is no significant research going on in the field, in the 20th century many new types of belts were introduced with different material selection as per the application but now, the level of exploration is on the urge to get over and so we don't find significant revolution in terms of research in the field.

Modern

Traditional

➢ New advance Research

Many new documents have been published on belt drives over the period of time. A total of 332 documents have been published on belt drive and 42 documents have been published in the last 42 years.
Advanced belt drives are manufactured which are an advancement in the field. Many companies are updating their equipment, breaking with tradition, and converting to cutting-edge belt drive systems as a result of advancements in materials, technology, and process engineering.
Numerous firms create high-quality goods that must adhere to strict industry standards and regulations during crucial procedures.

Contamination throughout the production process is unacceptable in the food, beverage, or pharmaceutical industries and can result in standing inventories, wasted goods, or recalls. Equipment must always be clean, and preventing contamination is of utmost importance. For instance, areas where food is handled frequently need to be washed down, which might contaminate the water with rust.

Boosting worker safety, optimizing internal procedures, and enhancing quality control measures all have positive effects on your bottom line in addition to the ones already mentioned. By removing many workplace safety risks with the help of advanced belt drive systems, you may increase worker and facility safety, decrease the need for overtime maintenance, and create a happier workforce with less organizational risk and liability.

RECENT RESEARCH DEVELOPEMENTS IN BELT CONVEYOR TECHNOLOGY (totalweblite.com)

➢ Scope of Optimization

Motors are used to provide rotational power, but they typically operate at too high a speed and too low a torque. Therefore, speed reduction between the motor and the driven machine is always needed. Belts and chains represent the major types of flexible power transmission elements. The high speed of the motor makes a belt drive ideal for the first stage of speed reduction. At low speed and high torque conditions, chain drives become desirable.

Drive efficiency depends on several factors, including load capacity, belt flexing resistance, speed, pulley size and belt tension.

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