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A Review on Cooling of Continuously Variable Transmission

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Abstract: *Automakers are continuously researching new technology in order to develop power train systems such that they reduce power losses in the vehicle. The most important key element in a passenger vehicle is comfort ride performance. The solution to achieve this is by which continuously variable transmission. Continuously Variable Transmission (CVT) uses variable adjustable drive ratios instead of discrete gears to obtain optimal engine performance. As CVT development proceeds, performance will always be going to increase and costs will be reduced timely which makes further development and application more desirable. Knowing its performance limitations will act as a guide for employment in different applications.The current paper reviews the state-of-the-art research on control of heat generation in continuously variable transmissions. The various methods to control generate heat in CVT are also discussed.*
Keywords : *Continuously Variable Transmission, Fins, Heat Transfer Area, Forced Convention.*

I. Introduction

CVT is an automatic transmission system which changes the diameter of input shaft and output shaft directly, instead of going through several no of gears change. CVT can generate infinite no of gear ratios. It has three major parts drive pulley, drive belt and the driven pulley. Front movable drive and centrifugal fan is mounted on drive shaft. Centrifugal clutch with frictional material adhered to its periphery and clutch drum which is connected to driven shaft, forms a driven pulley. When engine is running at idle condition, clutch will rotate but drum will be stationary. When vehicle starts (engine speed >engagement speed), clutch engages with clutch drum and vehicle starts moving. There is probability of slippage while engagement of clutch with clutch drums. Slippage occurs either when engine speed is nearly equal to engagement speed or at very high engine speed, because of which, friction is generated between frictional material (generally asbestos material) and clutch outer, and increase in temperature is observed at driven pulley. If amount of heat generation is more, it may lead to burning of centrifugal clutch which is not desirable for vehicle running. Heat generation is not desirable for the components inside CVT housing. Material properties of the components depend on temperature. It changes thermo physical properties on material. Temperature has an impact on strength /elasticity of drive belt. Belts tend to lose its elastic property at higher temperature. More slippage will occur due to less tension in belt, giving rise to loss in transmission efficiency. Due to increase in temperature, thermal stresses develop in the components which reduce its service life. To control this, design of CVT is done in such a way that ambient air is sucked inside CVT housing by centrifugal fan mounted on drive shaft.

II. Literature Review

In 2016 Johannes Wurm, Matthias Fitl, et. al.established a numerical model which is capable of calculating thermal conditions regarding a continuous variable transmission (CVT). This literature covers the mechanism and power losses of CVT-systems in detail but a thermal investigation is still not available. For this task. Computational fluid dynamics (CFD) is used. Transient simulations are not possible because of high computational costs. Therefore, the case has to be simplified to a steady-state problem. Multiple reference frame (MRF) is used for modeling approach but the prediction of the pulley surface temperature is misleading. Local heat input, e.g. from the belt and asymmetric flow conditions are mostlyaccountable for the inaccuracy. The innovation of this study is the thermal modeling of heated pulleys where the errors, causing from a steady state simulation, are reimbursed. Further advantages of the presented approach are the stability of the solution and the time efficiency. A time efficient method is developed in the present study which is skillful of computing the temperature distribution of a fast rotating heated disk that is locally cooled by forced convection. Figure 1 shows surface temperature distribution of the disk resulting from steady state simulation without temperature compensation. A simplified quasi-steady-state model is necessarybecause the computational time of a transient simulation is beyond feasible dimensions [1].

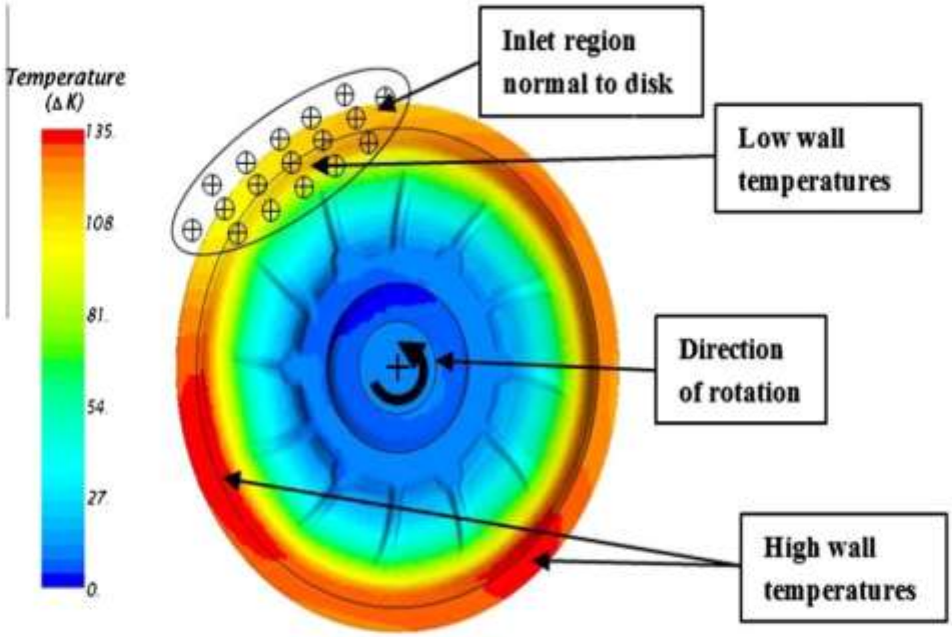

Fig. 1: Surface temperature distribution of the disk

In 2016 Mayur U Patil, KaushikBharadwaj et. al. studied the surface temperature around the pulleys of a CVT [2]. The research work includes design modification of CVT andexchanging material of the pulleys to increase heat flow rate. The temperature distribution is analyzed for different designs by using steady state thermal analysis tool in Ansys. At higher speed instances and clutch slippage conditions more heat is produced in CVT components .It also disturbs the service life of components if it is worked for a long run and at the same time performance is reduced. So, cooling of CVT is needed. The contact between V belt sidewalls and pulley groove is the main source of heat generation in CVT. Heat generation is reducedwhen design modification is done in CVT by providing fins and holes. Also change in material of pulleys to accomplish better heat dissipation properties. After modification it can be seen that secondary pulley temperature is reduced by 15.47^{0}C and primary pulley temperature is reduced by 12.67^{0}C. Heat transfer area is increased by 27.41 % after providing of fins. The temperature is reduceddue to large heat transfer area of fins and higher thermal conductivity of Al MMC. The comparison between base design and modified design is shown in figure 3 below.

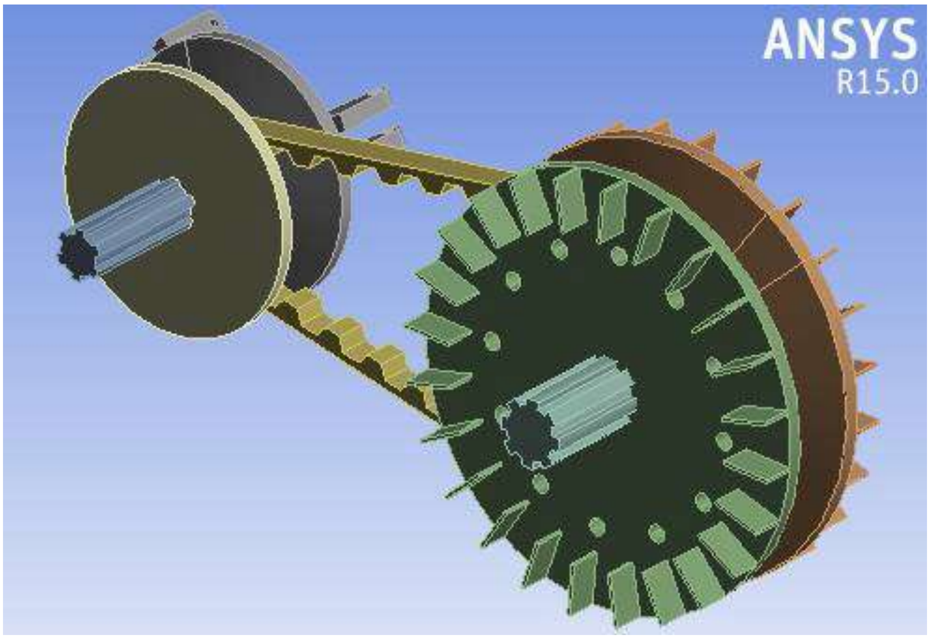

Fig. 2: Modified design of pulley based CVT

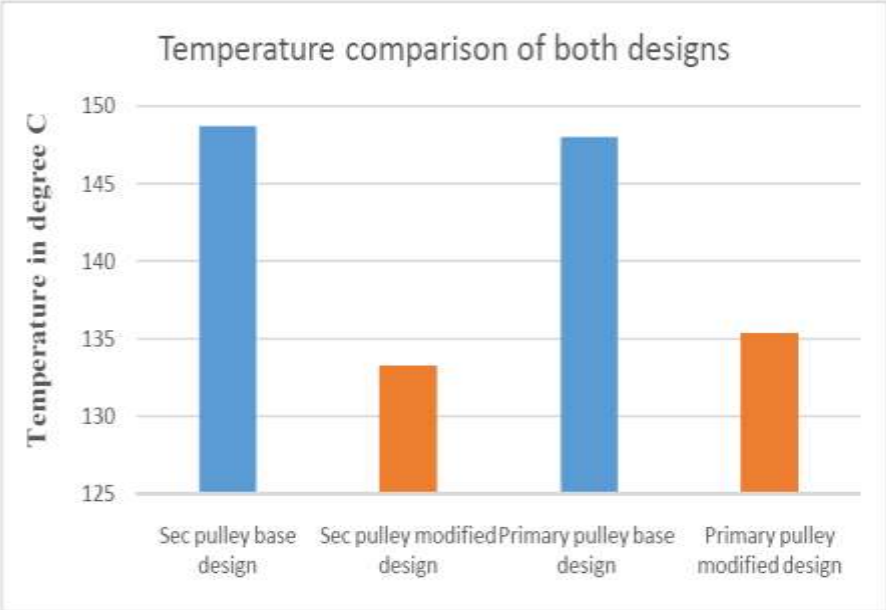

Fig. 3: Comparison of temperature for base design and modified design

In 2018 P. Sivakumar, P. Appalaraju et. al.developedmodel of CVT is done based on BAJA-SAE Continuous Variable Transmission setup [3]. It is further customized by increasing the surface area by addition of rectangular and cylindrical fins on secondary pulley's surface. Considering an average base temperature of CVT's driven pulley surface as 800C it is aimed at lowering the temperature to 600C. With help of heat transfer calculate the number of fins necessary using interpolation or iterative processes and then modeling the fins using Solid works and import the modeling into Ansys workbench. Utilizing the thermal module in ANSYS WORK BENCH, required steady-state thermal analysis is performed and its results are compared with theoretical calculations.There is a decrease in temperature by 21.8% using rectangular fins and nearly 5.67% only by using cylindrical fins. With rectangular fins, the mass of the pulley increases by 0.47% only but cylindrical fins with 6.16%. This concludes that rectangular fins are more effective in terms of mass, heat transfer, effectiveness and feasibility of manufacturing as well as the economy.

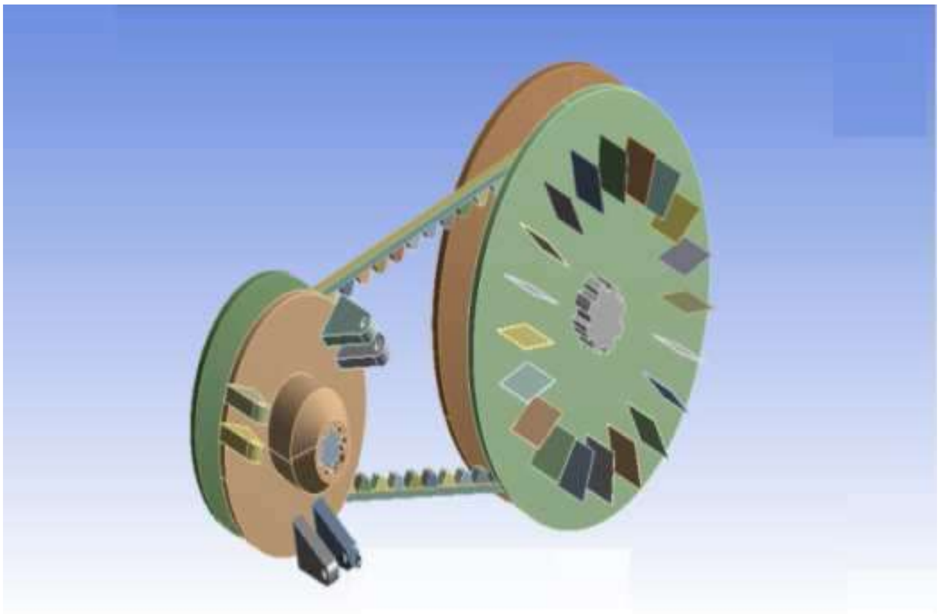

Fig. 4: Modelling of Secondary Pulley with Rectangular Fins on its Surface

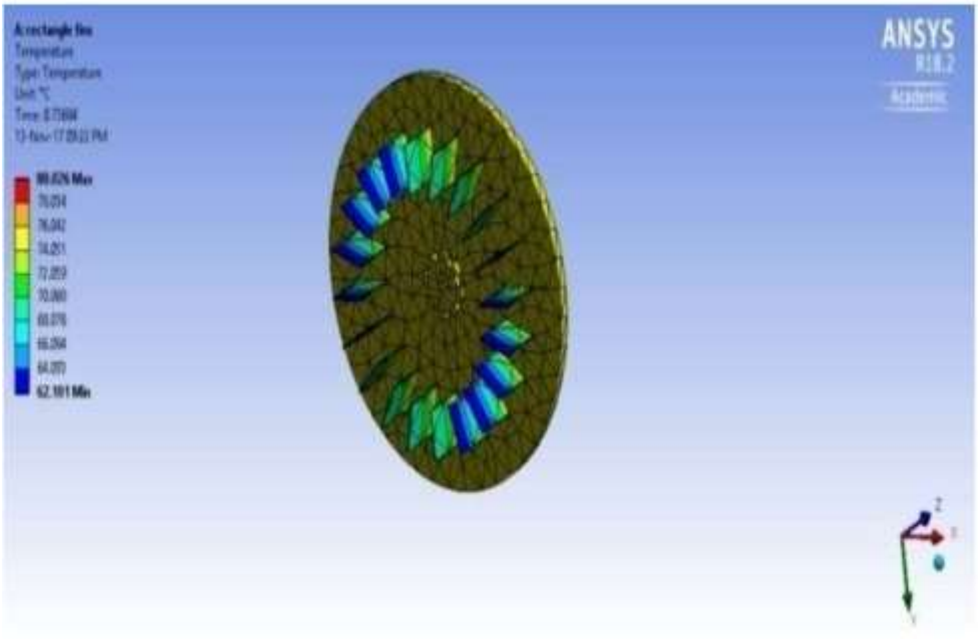

Fig. 5: Analysis of Secondary Pulley with Rectangular Fins on its Surface

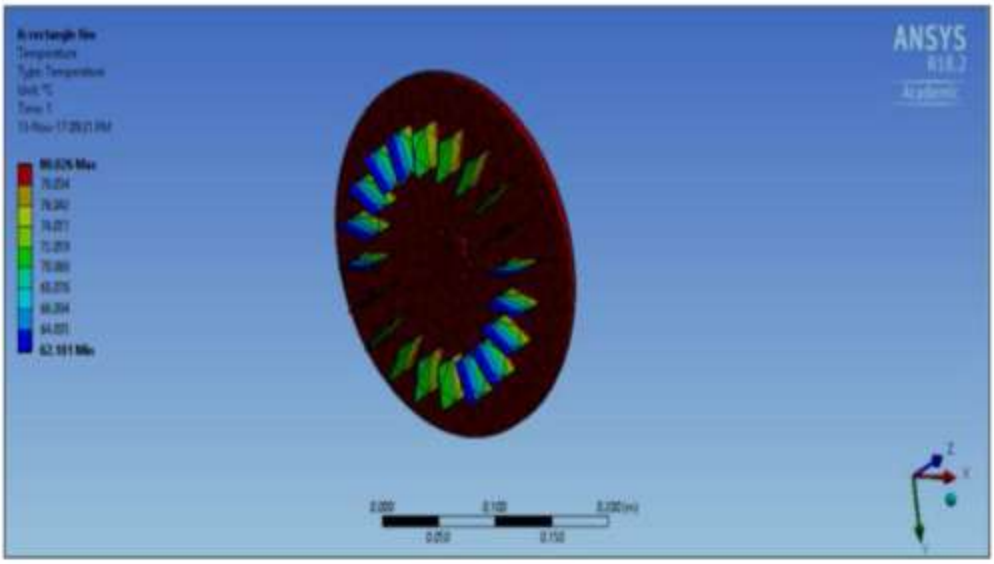

Fig. 6: Temperature Analysis of Secondary Pulley with Rectangular Fins on its Surface

In 2014 Snehal Vasant Dhongde and Vinilkumar Chandran identified the parameters causing change in temperature of CVT components and evaluated its surface temperature in accordance with changed parameters [4]. With reference to the experiments conducted with necessary design change inside CVT housing, which enhances cooling effect. The variables which determines air flow rate are studied and experimentally their effect on temperature inside CVT housing is observed. Keeping the previous variables unchanged, further design modifications related to air flow outline are done and growing effect of all variables is observed. Experiments were done on an 110cc scooter engine by following customer driving outline on chassis dynamometer. Results showed that design modifications proposed for improved cooling effect, has brought down temperature at CVT components. Therefore, desired cooling effect is observed inside CVT housing imparting better service life of CVT components. Factors which have impact on temperature of CVT works and inside CVT housing are calculated., There are three design modifications were made by considering the effectiveness of each parameter. Following are the modifications done in CVT:

1. CVT Outlet Duct modification
2. Insulator Plate modification
3. Fan with different Blades.

I. Comparative study and analysis

SR. NO.	AUTHOR	PARAMETER	DESCRIPTION
1	Johannes Wurm, Matthias Fitl, Michael Gumpesberger, EsaVäisänen, ChristophHochenauer	Temperature Distribution	Time efficient method is developed, which is capable of computing the temperature distribution of a fast rotating heated disk that is locally cooled by forced convection.
2	Mayur U Patil, KaushikBharadwaj, Sameer Sathwick, Baskar	Fins	To achieve better heat dissipation, increase heat transfer area A, which is done by using extended surfaces called fins. Increasing thermal conductivity will also increase heat transfer.
3	P. Sivakumar, p. Appalaraju, ch.Srikar, t. Sanjeevkumarreddy, y. Jayendrakumar& k. Vishnuvardhanbabu	Introduced cylindrical and rectangular fins	From the obtained results, there is an increase of surface area by 33.47% using rectangular fins while there is an around 32.94% increase in surface area by using cylindrical fins. There is a decrease in temperature by 21.8% using rectangular fins, nearly 5.67% only by using cylindrical fins.
4	SnehalVasantDhongde and VinilkumarChandran	Identify the parameters causing change in temperature of CVT components	Temperature near belt region is reduced by ~14% after modification, which will result in improved service life of belt. Temperature at driven pulley is decreased by ~20% which will curtail the probability of clutch burning while driving vehicle in city.

III. Conclusion

In Automotive applications a Continuously variable transmission is important for giving better fuel economy, reduced emissions and vehicle performance improvement. Certain new configurations of CVT designs focus on reducing heat generation by providing fins, high transfer areas etc. The current study addresses the state-of-the-art research accomplished towards understanding CVT heat generation methods. The performance of CVT may affect due to heat generation. Therefore, cooling strategy for CVT is important for evaluating the performance of CVT. Cooling of CVT is done by certain modifications in design which gives high heat transfer rates.

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