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DESIGN OF FRONT END ACCESSORIES FOR A TWO CYLINDER ENGINE

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ABSTRACT

The FEAD (Front End Accessory Drive) is one of the important systems as it is responsible for the optimum performance of major systems such as the cooling system & power steering system. The FEAD of an engine mainly consists of the accessories like alternator, water pump, power steering pump etc .The selection and design of the belt drive is necessary for the proper functioning of all other accessories. The main focus was on the design of the drive system for two cylinder engine. The initial system makes use of auto tensioner in tight side of the belt. This auto tensioner is removed in first proposal and is replaced by a manual tensioning mechanism on slack side of the belt drive. For this a bracket is newly designed for mounting of alternator which acts as a tensioning device. This design is further improved upon and simplified for 2nd proposal. The fea analysis of the alternator bracket is done for the static case only. The cost comparison of the new design has been done with existing design, which shows a significant reduction in cost.

Keywords: FEAD, Serpentine Belt Drive, Multi ribbed Belt

INTRODUCTION

The automotive industry is moving towards more and more compact engines, as a result of downsizing and weight reduction are seen as prime tools for getting better performance from a smaller and lighter engine. The advancement in the Engine technology with respect to the fuel injection system and engine management system is achieving new heights, at the same time the designers are focusing on making the Proper function of the FEAD system is necessary as it is directly responsible for the performance of the critical systems such as the cooling system, all the electronic and electrical devices getting power supply from the alternator. It is also indirectly involved in the easy handling of the vehicle as it accounts for the proper running of the power steering pump. The optimum operation of the FEAD is thus gaining more and more importance.

The FEAD is becoming compact and for the increasing load capacity of the belt drive, instead of the V belts, ribbed or multi v belts are used in conjunction with multi grooved pulleys. The engineers and designers are now focusing their attention on the NVH aspect of the FEAD system. The modern studies are aligned on reducing the noise from the belt drive, which is termed as belt chirp noise caused mainly due to the misalignment of the pulleys and the belt. The present studies are inclined towards the dynamic behavior of the FEAD system including the noise and vibration characteristics of the belt, the interaction between t he contact patch of the belt and the pulley.

The modern day FEAD which consist of three or more pulleys and a single ribbed belt is called as the serpentine drive. Tensioning devices are also very important as they maintain proper tension in the belt during its life which reduces on account of elongation of the belt. The most popular tensioning devices are the hydraulic and dry type of auto tensioners. Manual tensioning mechanisms are used on smaller and simpler system with less number of components.

FEAD Layout

The FEAD layout of the benchmark and exsisting engine is studied and two new proposal layouts are suggested. the simplified layouts are then compared and design calculation are made.

Existing Layout

The existing layout consists of a water pump, an alternator and the vibration damper or crankshaft pulley, along with belt tensioner and idler pulley. The layout of the existing system is shown below. This layout was adapted from the benchmark engine which helps in commonisation of the components.

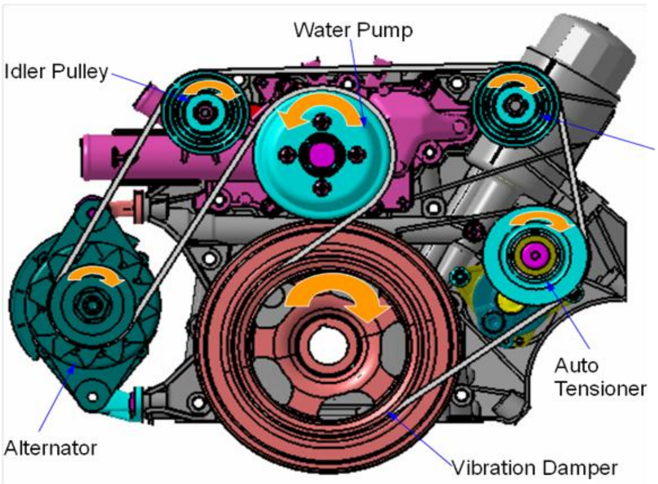

Figure 1. Existing layout

Proposal 1

The proposal layout consists of 5 no. of pulleys and a 4 PK belt. The auto tensioner is removed and the tensioning is provided by the alternator and its mounting bracket which act as the manual tensioning device. The figure below shows the layout of the proposal 1.

The alternator used is a reduced capacity alternator which suits the requirement of the application vehicle. It has slot on its upper part and can be pivoted on its bottom to the alternator mounting bracket. The pivot motion of the alternator provides for the tensioning of the belt.

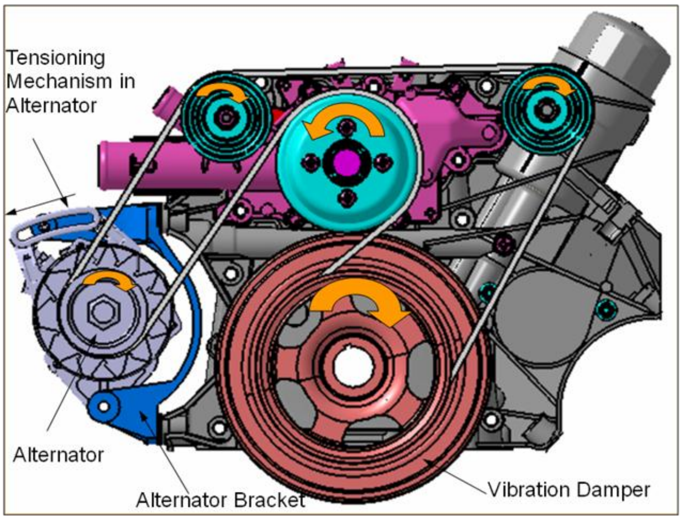

Figure 2. Proposed layout 1

The tensioning is provided with the help of a new design of mounting bracket which is used here, which can be seen in the figure above.

Proposal 2

The layout discussed above is further simplified and the no. of pulleys is reduced to three, with just the water pump, alternator and the vibration damper. Here also the same alternator arrangement is used for tensioning of the belt. The idlers are eliminated, which also reduces the belt length required significantly.

This is the most simplified layout which can be used; the main change as compared to the previous layouts is that, the direction of rotation of the water pumps changes from anti clockwise to clockwise direction. The FEAD drive becomes more compact and most simplified. The figure below shows this simplified layout

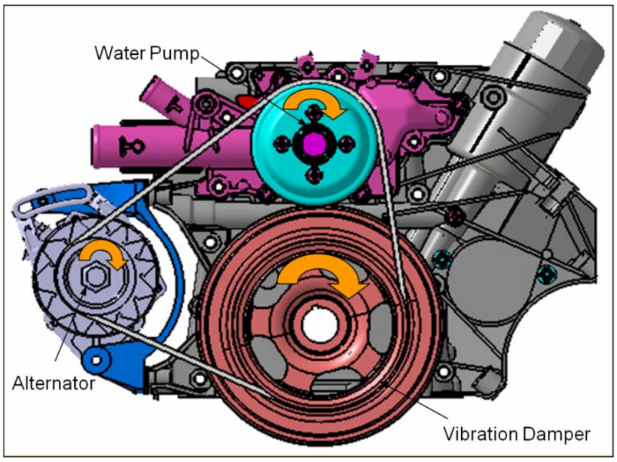

Figure 3. Proposed layout 2

Engine Duty Cycle

In the FEAD design process, an engine duty cycle is formulated for the further calculations are done based on this engine cycle. An engine duty cycle is to be determined for the further calculation of the Accessory belt drive system.

The cycle gives different speeds and corresponding % of time the engine operates at that speed. Unlike the EDC and MIDC which are standard cycle used for Emission testing of vehicles the engine duty cycle depends on the type of engine and its application, which is to be decided by the designers keeping in mind the application to which the engine will be subjected to.

Table 1. Engine duty cycle

Condition	% Operating Time	Engine Rpm
A	5	600
B	20	1000
C	45	2000
D	25	3000
E	5	4000

Drive Calculation

This chapter included all the factors taken into consideration for designing of a belt drive system and all the steps are explained with the necessary formulae and relations. The following steps are followed for the design calculation of the FEAD drive, given below is the schematic of the step by step procedure used in this drive design.

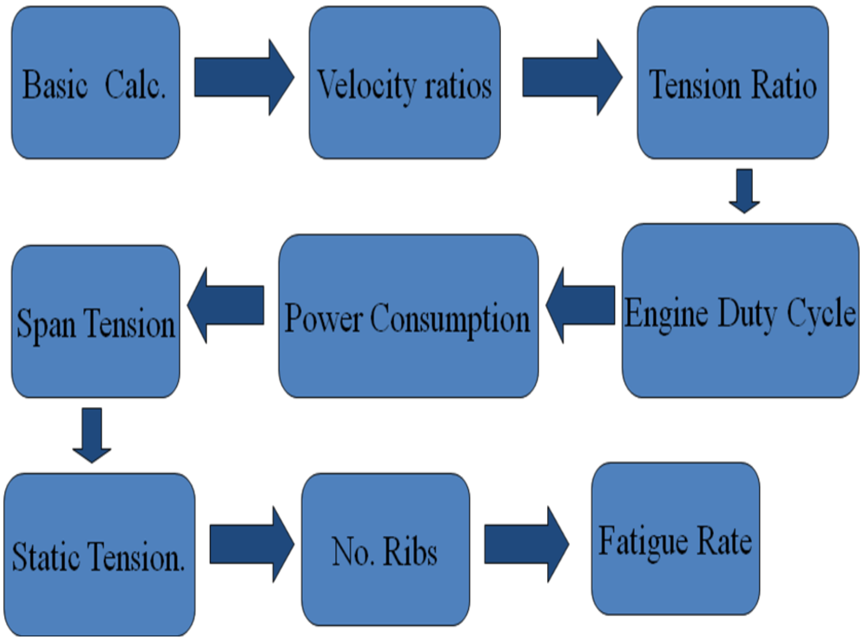

Figure 4. Steps in drive design

Sample Calculation

The steps mentioned above are used to formulate a Calculation template in M.S Excel. The following table represents the sample calculation for one of the engine duty cycle condition for the proposal layout shown in the figure below.

Table 2. Shaft Load Proposal 2

Sr No.	Pulley	Wrap Angle (AOC) deg	Tight side Tension,N	Slack side Tension, N	Shaft (Hub) Load, N
1	C.S Pulley	123	228.76	106.09	326.6293
2	W.P Pulley	119	228.76	195.86	86.55683
3	Alt Pulley	118	195.86	106.9	204.6191

Table 3. Sample calculation Proposal 2

Parameter	Units		C.S Pulley	W.P	Alt r
Effective dia. Db	mm		146.82	109	64
Line Differential, hb	mm		1.5	1.5	1.5
P.C.D, dw	mm	149.82	149.82	112	67
Velocity Ratio, V.R			1.00	1.34	1.67
Arc of contact, A.O.C.	deg.		123	119	118
Arc Length, A.L	mm		157.59	113.19	65.90
Span length	mm		160.97	222.85	195.57
	m		0.16097	0.22285	0.19557
Belt Length	mm	916			
Speed, N	rpm	3600	3600	4816	8050
Belt Velocity, V	m/s	28.4			
Mass of Belt, m(Per rib)	kg/m	0.0230			
Speed of C.S	rpm	900	900	1204	2013
Belt Velocity, V	m/s	7.06	7.06	7.06	7.06
Power consumption, P	kW		0.8376	0.21	0.6276
Effective Pull, F	N		118.70	29.76	88.94
Design Tension Ratio, T.Rde			2.6	2.5	1.82
Span Tension	N		T1	T2	T3
			192.8853903	163.13	74.19
Calculated Tension Ratio T.Rc			2.60	1.18	2.20
No. of Ribs		4			
Additional Tension, Ta	N		31.90	31.90	31.90
New Span Tensions	N		224.78	195.02	106.09
Span Length	m		(L1)0.16097	(L2) 0.22285	(L3) 0.19557
Static Tension, Ts	N	177.85			
Fatigue Rate, Fr		0.26	0.02	0.04	0.20

The bending frequency is calculated based on the formula in the section above, it is found to be 21.5 Hz, which is well below the specifications of the belt manufacturers.

FEA Analysis

The Mounting Bracket for alternator along with the alternator is used as a manual tensioning device in the new FEAD layout. Thus the FEA Analysis of the alternator bracket is necessary to check whether the new proposal of manual tension works properly under the highest belt

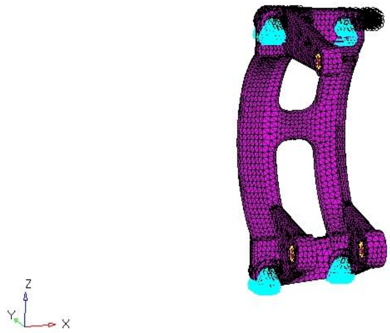

Figure 5. Meshed and Constrained model of alternator bracket.

Hyper mesh is used as analysis tool for the static analysis of the alternator bracket. The following figure shows the meshed bracket structure with the boundary conditions. The meshed used is Tetragonal mesh and the side containing the mounting points is constrained.

The maximum belt tension is used to evaluate the hub load acting on the alternator pulley, which is transferred to the mounting points of the alternator. The counter plot shows the region of maximum and minimum stress concentration all over the bracket. Then the induced stress values are compared to the yield strength, of the material to be used for manufacturing.

The FEA analysis of the bracket shows that the maximum stress which occurs is 10.8 N/mm^2, which is very much less than the Yield strength of C.I which is 250 N/mm^2. Thus the bracket is safe under the static load condition.

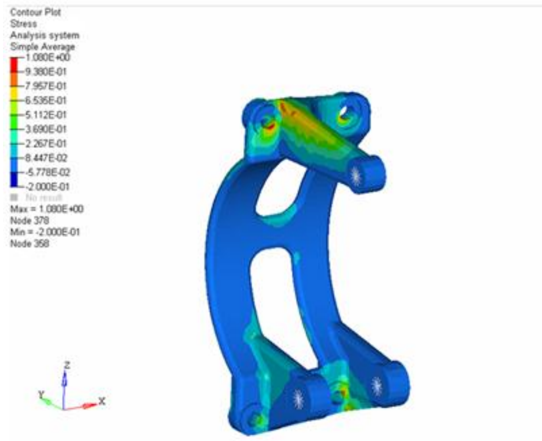

Figure 6. Stress Distribution

CONCLUSION

The different layouts for the engines FEAD system have been studied and calculations are made, the simplification achieved in each of the concepts compared with the benchmark engine and the existing layout. The no of parts are reduced and thus it also leads to a significant cost reduction which is tabulated below.

Table 4. Comparison of FEAD layout

	Benchmark	Existing	Proposal 1	Proposal 2
Vibration damper	*Y*	*Y*	*Y*	*Y*
P.s pump	*Y*	*N*	*N*	*N*
Ac comp	*Y*	*N*	*N*	*N*
Idlers	*Y*	*Y*	*Y*	*N*
Auto tensioner	*Y*	*Y*	*N*	*N*
Alternator	*Y*	*Y*	*N*	*Y*
Water pump	*Y*	*Y*	*Y*	*Y*
Belt profile	*6PK2271*	*4PK1664*	*4PK1631*	*4PK915*

Thus from the above table it is clear that the proposal two is the most simplified of the two layouts that have been worked upon. Based on the above table, the cost analysis of the FEAD layouts is done. The cost of the bracket to be used in the new proposal is estimated from its weight, cost of the material and the machining cost. The proposal two shows the maximum reduction in cost of about 23 % as compared to the existing FEAD layout.

Table 5. Cost comparison of FEAD layouts

Part	**B.M**	**Existing**	**Proposal 1**	**Proposal 2**
Vibration damper	500	500	500	500
P.s pump pulley	500	---	---	---
Ac comp pulley	820	---	---	---
Idlers	300	300	300	---
Auto Tensioner	500	500	---	---
Alternator pulley	1150	1150	1150	1150
Water pump pulley	110	110	110	110
Belt	300	250	240	200
Bracket(CI)	---	---	200	200
Total cost	4180	2810	2500	2160
% Cost reduction compared to existing layout			11%	23%
Bracket(Al)	---	---	160	160
Total cost	4180	2810	2460	2120

Cost in INR

Now considering the performance of the FEAD layout in term of fatigue rate, the proposal 2 has a lower fatigue rate as compared to the existing and proposal layout.

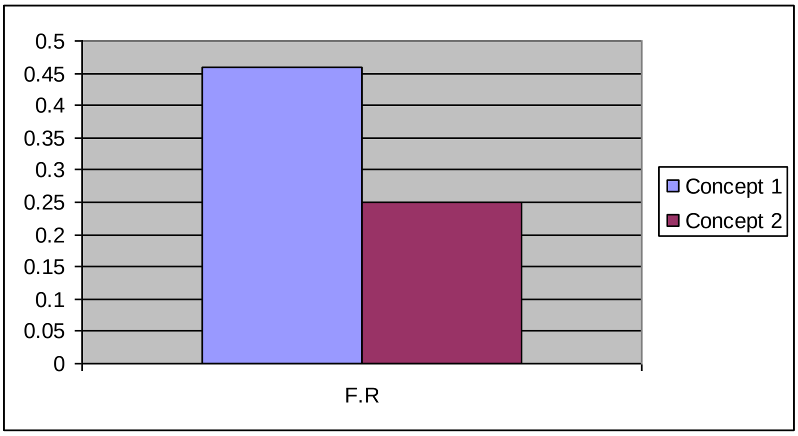

Figure 7. Comparison of fatigue rate

FUTURE SCOPE

The future scope of work is as follows

- Fitment trial of the new alternator mounting bracket on engine dynamometer.
- Design of water pump for the clockwise rotation and redesigning the water pump as per the flow requirement of engine.
- Modifications in the timing case housing, as per the new water pump design.

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