Comparative Design Analysis of Variants of Propeller Shafts & Scope of improvement in terms of Serviceability for Heavy Duty Application

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***Abstract* - In the modern Automobile Industries, where the changing trends & technologies exists and keeps upgrading. And with the mining segments getting deeper and multiple product base requirements, the Automobile markets demands for all new variant type in accordance to the Driveline application. In the current paper the most heated issue due to such changing trends has been put forward with reference to the Industrial based facts & Case studies. We have put up the basic information of the primary types of Heavy Application Propeller shafts & Its Key Components in detail that comprises of the UJ Kit, Tube Shaft, Flange Yoke, Slip Yoke along with its functioning. In the current work we have presented the analysis of two different shaft designs or say Variants used & the practical fitment trial job has been conducted. Also it presents the weight reduction & Cost Reduction features of using a different shaft design along with the improvement in terms of serviceability.**

***Index Terms* - Propeller Shaft, Variants, Modularization.**

1 INTRODUCTION

The propeller shaft selection is very specific in terms of application & hence is designed based on various typical aspects prevailing. The major parameters which need to be considered in terms of designing is the Torque requirement i.e. Torque input, Duty cycle i.e. Gross Vehicle weight, UJ working angle; Other key parameters also include the Gear box design for gear transmission ratios & transmission efficiency for defining of the Torque. Now with the ever changing requirements & applications the shafts are designed with the varying tube lengths without affecting in its properties [1, 7].

The Basic function of a driveshaft is to transmit power from one point to another in a smooth and continuous action. In automobiles, trucks and construction equipment, the drive train is designed to send torque through an angle from the transmission to the axle (or auxiliary transmission). The driveshaft must operate through constantly changing relative angles between the transmission and axle. It must also be capable of changing length while transmitting torque. The axle of a vehicle is not attached directly to the frame, but rides suspended by springs in an irregular, floating motion. This means the driveshaft must be able to contract, expand and change operating angles when going over bumps or depressions. This is accomplished through universal joints, which permit the driveshaft to operate at different angles, and slip joints, which permit contraction or expansion to take place [7].

1.1 Propeller shaft: Basic Components and Functioning Requirements

Depending on application of vehicles Shafts can be designed as below:

- One piece drive shaft: Simple tube and yoke combination
- Two piece drive shaft: Two shafts connected with a center bearing
- Three piece drive shaft: Three shafts connected with two center bearings

- Slip in tube drive shaft: The slip-in-tube drive shaft is that improves crash safety. It can be compressed to absorb energy in the event of a crash, so is also known as a collapsible drive shaft.
- End Yoke: Casting part; Helps to minimize noise and vibration to keep the driveline running smooth are used to provide the necessary rigidity required to maintain bearing alignment under torque loads
- Universal Joint (UJ): Forged component; Is a joint of pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft or coupling that allows the rod to bend in any direction
- Tube Yoke: Helps to minimize noise and vibration to keep the driveline running smooth
- Tube/ M.S. Shaft: It's a hollow shaft that helps in transmitting of the cyclic loads
- Tube Flange: Used for axially transmitting/ connecting loads from Gear box to Differential end

- Centre Bearing: Required for centre bearing assembly where the lengths need to be reduced. Also, it reduces noise and vibration and maintains the proper driveline angle to maximize driveshaft and component life
- Intermediate End Yoke: Helps to minimize noise and vibration to keep the driveline running smooth
- Axle End Yoke: Helps to minimize noise and vibration to keep the driveline running smooth
- Strap Bolts: Used for assembling the components
- Snap Ring: Serves for the locking purpose of the UJ assembly with flange yoke & tube yoke.
- Slip Yoke: It is that component which absorbs the axial movement of the vehicle thus allowing for changes in length of the Driveshaft
- Dust Cap: Used to avoid entry of dust
- Split Washer: Used for proper sealing & locking purpose

Below is the exploded view of a two piece propeller shaft.

Figure 1. Exploded view of the Gearbox side assembly of first piece [7].

Figure 2. Exploded view of the axle side assembly of second piece [7].

2 INDUSTRY BASED CASE STUDY

In this section different aspects prevailing in modern automobile industries has been put forward wherein further scope exists to bring down these burning issues.

It is a case study of a leading Automobile industry AMW MOTORS LTD. INDIA [6], where in more than 70 variants exists including Regular & Stringent Models. Still along with the new Project a change based on the frame length is introduced which some or the other way brings a new tube shaft into the scenario. Hence due to the existence of multiple variants & Huge money is involved in piling up of the inventory in SAP which more or less leads to dead Inventory & monetary losses. This also leads to the rework of the Non Moving shafts for the conversion of the nearest required available shafts which ultimately involves below add on costs:

1. Manpower, 2. Overhead Cost, 3. Supervisory Cost, 4. Material Cost, 5. Reduction in the Life (in Hrs.) of the propeller shaft. 6. Failure issue of Shaft rises

2.1 DESIGNING OF THE MATRIX FOR THE MODULARISATION PURPOSE

After Analysis the selection of shaft can be made by the set of combination required as mentioned below:

- Different Series applications i.e. based on the Torsional values & Tube shaft diameter – Thickness Aspect.
- Application based- HL, TP, TM, CP
- Type of Suspension to be used. (Bogie/ Bell Crank)
- Type of Gearbox used (Capacity- 6 Speed or 9 Speed)
- Type of Suspension usage
- Survey with different variants ranging from 16 Ton to 49 Ton Capacity.
- Technical aspects in terms of Drive Ratio of Veh.- 6X4, 8X2, 8X2; Tube Dia. & Thickness of Tube.

Table 1: Propeller shaft Technical specification Matrix, [6]

	Model Specifications						Technical Specifications					
Description	**Model Name**	**Drive**	**Model Variant**	**Cab/ Cowl**	**Suspension Type BC/Boggie**	**GB Type**	**Series**	**Tube Length**	**Tube Dia.**	**Tube Thickness**	**Drive Side Flange Dia.**	**Diff. Side Flange Dia.**

3 FEATURES OF EXISTING VARIANT & INTRODUCTION OF NEW VARIANT

- Comparative Analysis of two different Shaft Series Types i.e. 1710 & C 2040

3.1 FEATURES OF 1710 PROPELLER SHAFT SERIES

1710 Series- Flange Design

- It has Free Movement of Rubber
- Normal Companion Flange design which is fixed type for the coupling end
- MSTS assembly with Nut in the coupling shaft

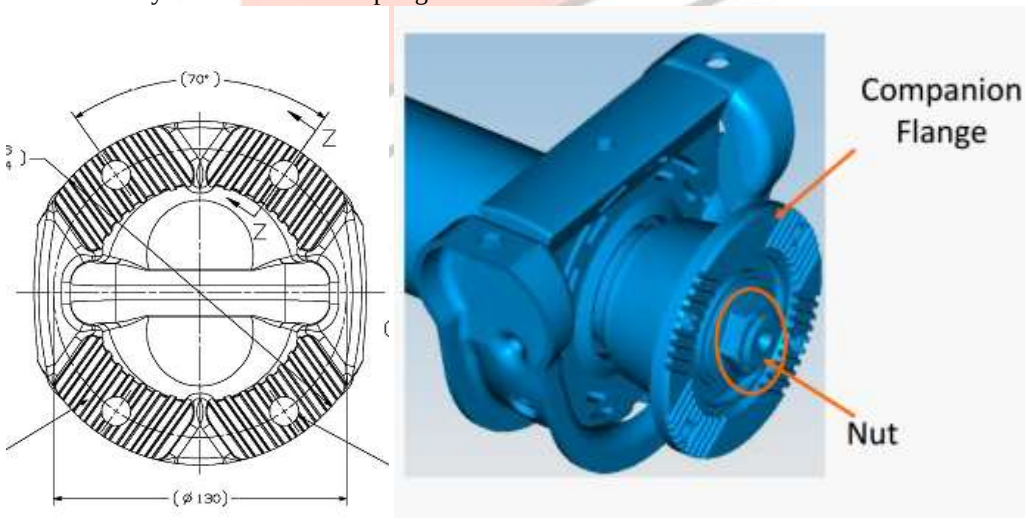

Figure 3: 1710 Series Flange design of a companion Flange, [6]

1710 Series- Flange Design

- Relube Type
- Grease Nipple
- Bearing Plate with Bolt Clamping
- Forged UJ Kit

– 2 Lip-Seal with Slingers

Figure 4: 1710 Series UJ design, [6]

3.2 COMPARATIVE ANALYSIS OF TWO VARIANT TYPES BASED ON THE PROPOSED DESIGN

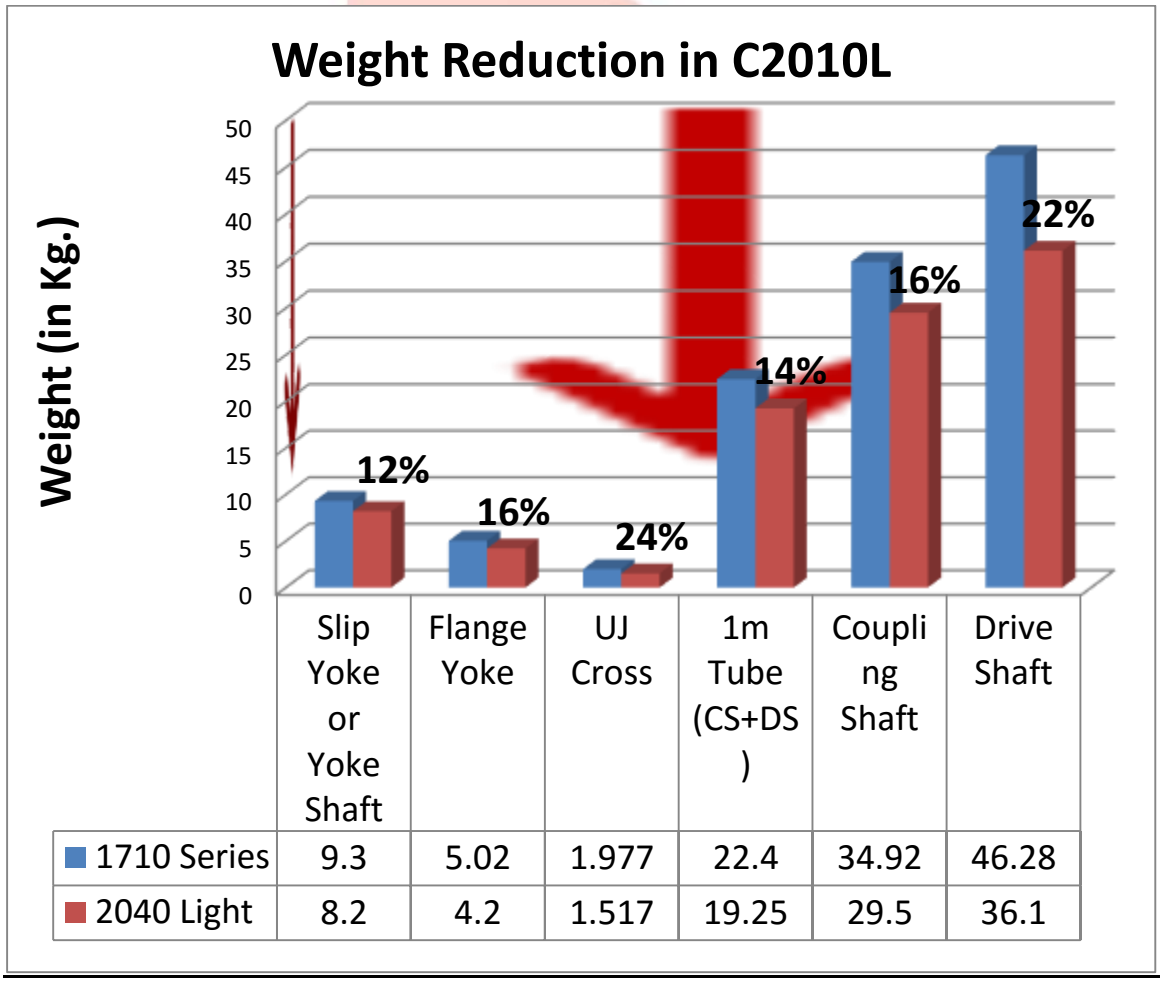

Figure 5: Comparison of two specific variants in terms of weight reduction, [6]

3.3 FEATURES OF C2040 PROPELLER SHAFT SERIES

C 2040 Series- Flange Design

- 2040 Series
- Retainer Plate for Better support
- Light Weight Cast Companion Flange
- Better Clamping Design–CF to MSTS to avoid Nut loosening issue (Serviceability improvement Point- Anti Rotation Hex. Bolts & Washer

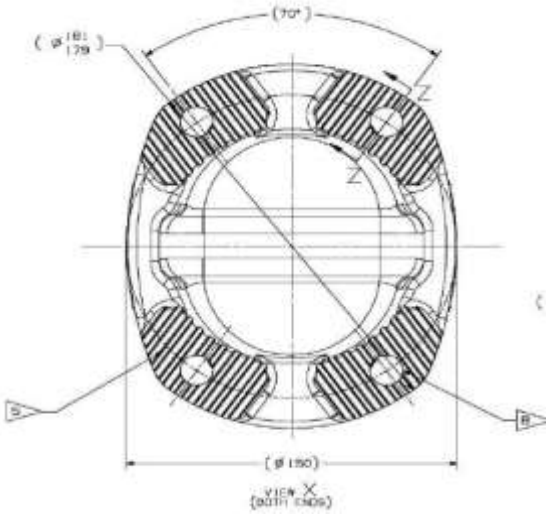

Figure 6 a: Side view, C 2040 Series Flange design of a companion Flange, [12]

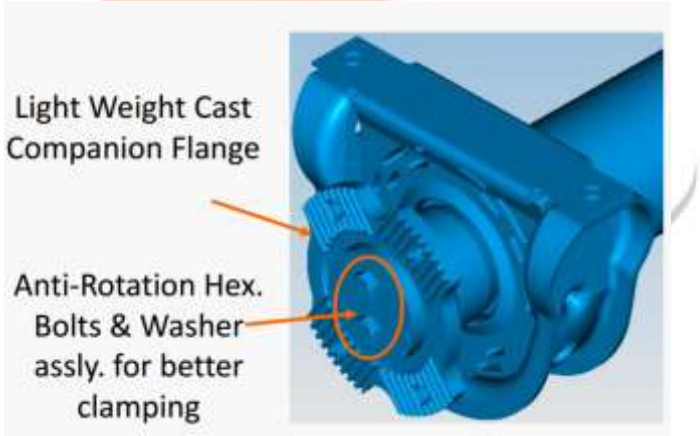

Figure 6 b: C 2040 Series Flange design of a companion Flange, [13]

C 2040 Series- Flange Design

- UJ Kit Lubricated for 1 Lac Kms / 3000 Hrs.
- No Grease Nipple
- If Play exceeds do Refurnishing
- Cold Forged UJ Enhanced Strength
- 3-Lip Seal with Slingers

4 FITMENT & TRIAL REPORT OF C 2040 SHAFT

Trial feedback for sample- 1

- For the first sample prepared the slip Observed was found to be 130 mm which is not acceptable as per the norms as the allowable slip limit is 120 mm only as the higher slip value will lead to higher stress levels during articulation of the shafts & will ultimately damage the shaft joint.

Tube length- 902 mm
Flange to flange length- 1510 (collapse length) +120(slip in mm) = 1630 mm
Yoke to center length- 1466 mm

Figure 7: Fitment Trial of Sample-1, [13]

Trial Feedback for sample-2

- Later the design changes were incorporated due to the practical aspects considering the fitment issues of the frame & gearbox end the practical difference of approximately 12 mm was observed. Hence the same was reduced in the tube length to meet the practical parameters & after trials was found to be ok.
- After marking on collapse location open slip dimension is found to be 115mm

Below changes were incorporated:
Tube length – 890 mm
Flange to Flange in Unladed – 1618 mm (1498 mm of Collapse length + 120 mm slip)
Yoke to Center length - 1457 mm

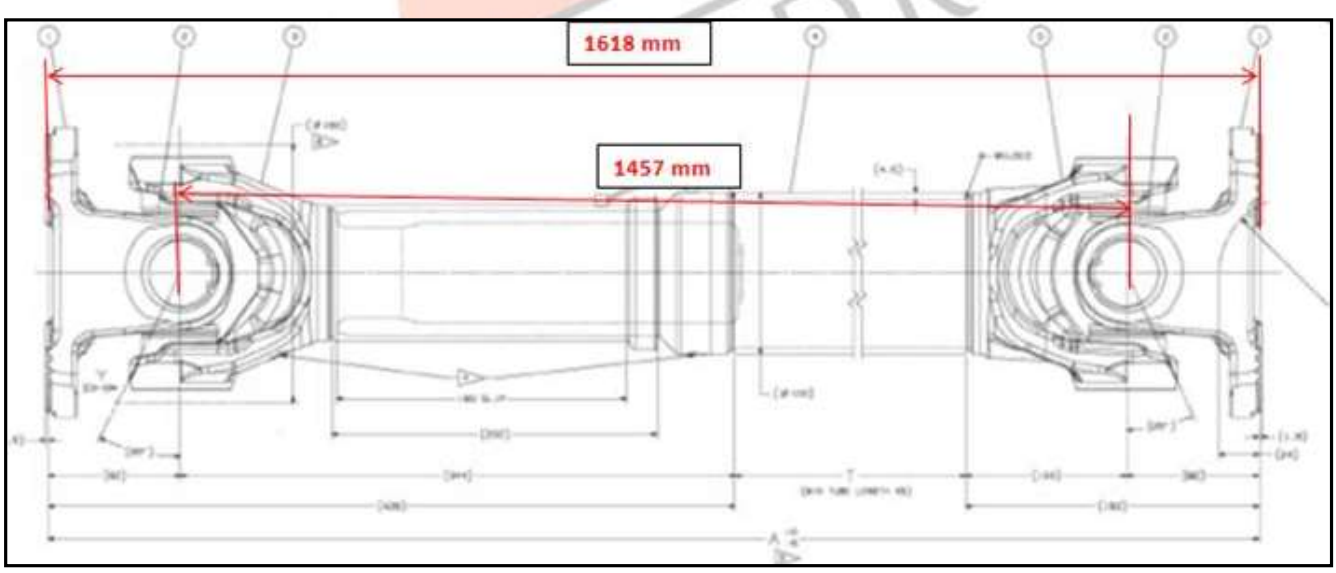

Figure 8: Design changes in the initial sample, [12]

Figure 9: Slip measurement, Fitment trial of Sample-2, [13]

4.1. TECHNICAL FEATURES OF C 2040 SERIES

- ✓ Advanced Design Flange Yoke
- ✓ Casting with weight Reduction pockets
- ✓ Less weight & cost reduction
- ✓ Overall 15% weight Reduction including DS & CS
- ✓ Service Free UJ Kits & Slip Joints
- ✓ Smaller Swing Dia.
- ✓ Lube for Life
- ✓ Muff can Design Slip Joint
- ✓ 140 mm Slip Movement, Allowable safe Max slip 120 mm
- ✓ Low Noise & Vibration
- ✓ Standard one slip

5 CONCLUSION

From the above sample comparative analysis & Fitment trial reports below are the key conclusions:

I. The Fitment trial satisfies the implementation perspective of the compact type shaft design that is C2040
II. Also we have observed a good weight reduction approximately 4kgs in Coupling & 8 kgs in Drive shaft based on the design features which has been presented in a comaparative bar graph also.
III. The results also present that there is a cost saving of 1.5-2% by changing the variant type
IV. Some of the technical features signifies that it is better in terms of serviceability because of the self lubricating feature.

6 FURTHER SCOPE OF WORK

From the above study we have a lot more of scope in the change of design & material composition for the Tube shaft & design change for the improvisation in the failure of the other components also. Further there is a scope in improvement to the failures related to the Universal joints, seals, welding area of the tube. Secondly, there is a dire need for the introduction of the modularized design which will help overcome many of the real life problems where the application based different models are concerned. A commonised design will be much more appreciable in bringing down the existence of the multiple variant concept. This will not only be beneficial till the manufacturing part but also in the after market product sale it will remain more demanding.

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