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Study of Materials, Costs and Processes Involved in Critical Components for Infinitely Variable Transmission System

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Abstract— The Infinitely Variable Transmission (IVT) system is designed to study the various characteristics like Torque, Power and Efficiency across the Speed. The components from IVT are designed with the considerations of various factors like material, cost, ease of manufacturing and the reliability of the system. The basic design of the IVT system and its components are done with the 3D modeling software CATIA V5 R20 version. The drawings created for the each and every component for the manufacturing to assemble the IVT experimental setup. This study explains the costs analysis of the IVT, manufacturing processes involved for the critical parts of the IVT. The main objective for this study is for better optimization of costs, raw material, manufacturing processes and time. As per the bill of material, standard parts purchased and main components of IVT manufactured with suitable processes

Key words: Infinitely Variable Transmission (IVT); manufacturing processes; Cost analysis of IVT

I. Introduction

This discussion is all about materials, costs and processes involved in the manufacturing of all IVT components and assembly. Figure 1 shows the infinitely variable transmission system design and assembly. The purpose of this design project was to improve upon an existing Infinitely Variable Transmission (IVT) design for use in the Mini Car.

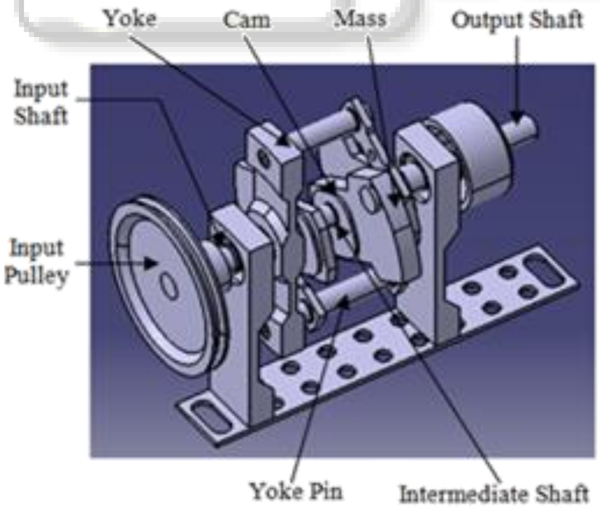

Fig. 1: IVT Design and Assembly

The project action plan contains many phases as discussed below. Data collection phase involves the collection of reference material for project concept. The idea for IVT is taken from the book ingenious mechanisms for designers and inventors. In the phase System Design comprises of development of the mechanism so that the given concept can perform the desired operation. The system design also determines the system components and their shape and overall dimensions. In the phase Mechanical Design, the parts mentioned in the bill of material is designed for stress and strain under the given system of forces and appropriate dimensions are derived. The standard parts are selected from the PSG design data handbook.

For the next phase Production Drawing Preparation, Production drawings of the parts are prepared using the 3D modeling software CATIA V5. The 3D design and 2D drawings are made with the same software with appropriate dimensional and geometric tolerances. Raw material sizes for parts are also determined. In the phase Material Procurement & Process Planning, material is procured as per raw material specification and part quantity. Part process planning is done to decide the process of manufacture and appropriate machine for the same. The next phase is manufacturing parts are produced as per the part drawings. In the phase Assembly of the IVT test rig, assembly of the device is done as per assembly drawings. Test and trial is conducted on the IVT test rig for evaluating the performance.

II. Objectives of the Study

The following are the objectives for this study –

1) The main objective of this study is to optimize the cost of manufacturing for IVT test rig.
2) To optimize the 3M recourses, machine, man and money to job get done within a time and allowable budget.
3) The Infinitely Variable Transmission (IVT) system is designed to study the various characteristics like Torque, Power and Efficiency across the Speed.
4) The objective is to understand the construction and operation of IVT and determine where improvements can be made.

III. Process Description for the Parts

A. *Facilities Available:*

The following facilities to carry out fabrication work are available at the machine shop site.

– Center lathe
– Milling machine
– DRO – Jig boring machine
– Electrical arc welding
– Variable speed drives for motor
– Electronic load meters
– RPM meters

B. *Input Shaft:*

The torque from engine is transmitted to the Input shaft via V-belt and pulley drive. The Input shaft transmits the torque to the yoke assembly. Input shaft is connected to the yoke assembly; yoke is mounted on the input shaft. The material for the input shaft is selected as per the PSG design data book. The material specification for input shaft is grade EN24. The initial raw material size for the process is 40 mm in diameter and 90 mm in length.

For the input shaft 0 to -0.02 mm tolerance provided for the functional faces to get better fitment in the assembly. The two dimensional drawing for input shaft is provided for the machine operator as shown in figure-2.

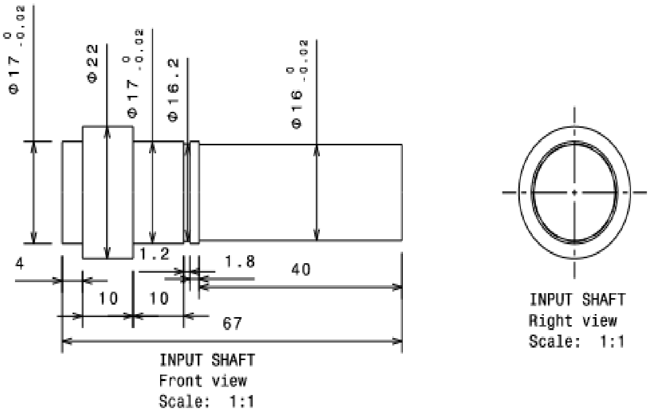

Fig. 2: Drawing for the Input shaft

It is required to do number of operations on the raw material to get finished part. For the input shaft several numbers of operations required to get the final part ready for assembly. First, Clamp stock in the three jaw chuck on the lathe, it will take around 20 minutes time for the setting. Facing both sides is required to get the designed length for the input shaft. The part is mounted in three jaw chuck on lathe for the facing operation to get 83 mm length. Facing tool is used as a cutting tool and vernier caliper is used to measure the length, it takes 5 minutes to done this operation. Turning outer diameter to 30 mm through length requires turning tool. Lathe operator takes the 5 minutes for the setting and 10 minutes for the machining, total time required for this operation is 15 minutes.

Step turning outer diameter to get 25 mm diameter through length 69 mm requires centers supports and carrier fixture on lathe. Turning tool used for the turning operation and vernier caliper us used to measure the length. Operator takes the 14 minutes time for this operation on the lathe machine. The same operation repeated for the outer diameter 24 mm through length 67 mm, with the same fixtures and measuring instrument it took 8 minutes for this operation. Repeated the same operation again for the 22 mm through length 62 mm with the same fixture and it will take only 4 minutes for this time to the operator. The final step turning outer diameter to the 16 mm through the length 40 mm is requires the 6 minutes with the same setting on the lathe.

C. Cam

The cam is mounted on the intermediate shaft, it is a hollow shaft which having a offset bore for the arm assembly shaft. The intermediate shaft having three cams mounted on it. The offset shaft means that any force acting radially on the cam is translated into a moment which acts on the shaft. This is because of the offset from the center of the cam, creating a moment arm.

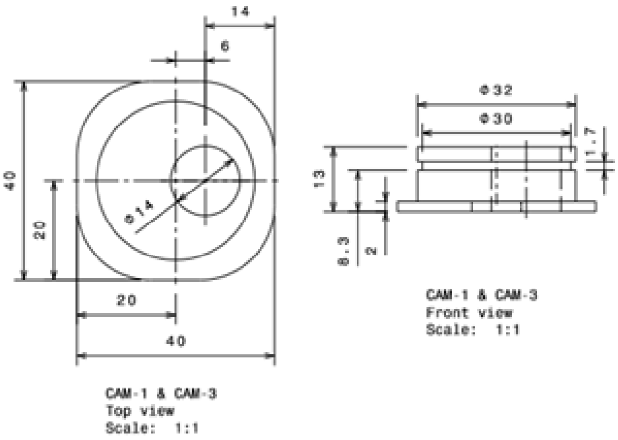

Fig. 3: Drawing for the Cam

The figure 3 shows the tow dimensional drawing provided to the machine operator. From the PSG design data book EN 24 grade material is selected for the cam. The blank size for the cam is 50 mm diameter and 40 mm length.

The raw material is clamped in four jaw chuck on the late and it takes 25 minutes time for the setting to operator. 12.5 mm diameter drill made throughout the thickness with the twist drill. It takes 15 minutes for setting the machine and 10 minutes for the machining. Boring operation performed for 14 mm diameter through the thickness with boring tool, it takes 15 minutes for the setting and 10 minutes for the machining. Then for the turning outer diameter for 44 mm through the length turning tool used, it takes 5 minutes for machine setting and 10 minutes for the machining the job. Then turning outer diameter for 32 mm through length 14 mm with turning tool, it takes the 5 minutes for the machine setting and 10 minutes for the machining. Groove turning as per the profile with parting tool takes 10 minutes for the machine setting and 6 minutes for the machining.

The other two cams are manufactured with the same operations according to the dimensions from the drawing.

D. Mass:

The figure 4 shows the tow dimensional drawing for the mass which provided to the machine operator.

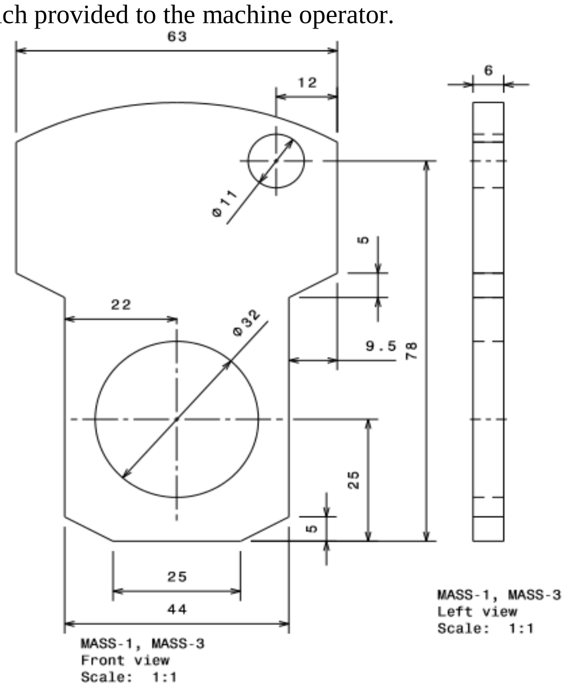

Fig. 4: Drawing for the Mass.

The mass is mounted on a cam which is on intermediate shaft. There are three masses mounted such a way that, the balancing of the system has been considered. Central mass is equal in weight than the addition of other two masses at the side and 180 degree rotation with each other. Material EN9 grade has been selected from the PSG design data book for the masses. The raw material is gas-cut blank plate.

The raw material is clamped in the machine vice for the milling operation, it required 15 minutes for the machine setting. Facing both sides on machine vice with facing cutter takes 14 minutes. Then clamp stock is mounted on 4 jaw chuck on lathe and the setting time required is 25 minutes. For the drilling 18.5 mm diameter through thickness with the twist drill takes 15 minutes for the machine setting and 10 minutes for the operation. Then boring operation is performed for 32 mm diameter through thickness with boring tool, it takes 15 minutes for the machine setting and 10 minutes for the operation. Drilling 10.5 mm diameter with a twist drill takes 10 minutes for machine setting and 3 minutes for the operation. Then the reaming operation is performed for 11 mm diameter with a reamer, it takes 10 minutes for the machine setting and 6 minutes for the operation. The other two masses are manufactured as per the dimensions mentioned in the drawings with the same operations.

E. Bill Of Material:

17	Input Shaft	1	EN24(alloy steel)
16	Cam -1	2	EN24(alloy steel)
15	Cam - 2	1	EN24(alloy steel)
14	Connecting Lever	3	EN9(plain carbon steel)
13	Mass - 1	2	MS (mild steel)
12	Mass - 2	1	MS (mild steel)
11	Clutch Housing	1	MS (mild steel)
10	IP Bearing Housing	1	EN9(plain carbon steel)
9	OP Bearing Housing	1	EN9(plain carbon steel)
8	Intermediate Shaft	1	EN24(alloy steel)
7	Output Shaft	1	EN24(alloy steel)
6	Yoke	1	EN9(plain carbon steel)
5	Yoke Pin - 1	1	EN24(alloy steel)
4	Yoke Pin - 2	1	EN24(alloy steel)
3	Connecting Pin	3	EN24(alloy steel)
2	Base Plate	1	MS (mild steel)
1	Base Structure	1	MS (mild steel)
Sr. No.	PART DESCRIPTION	QTY.	MATERIAL

Table 1: Bill of Material

The components enlisted in the BOM these are manufactured in the machine shop. The other components which are not mentioned in the BOM they are standard and purchased by market. The materials selected from the PSG design data book for the all components. The theoretical calculations have been made for stress strain analysis of each and every component. With the resulting dimensions according to the calculations we made 3D design and then the drawings. The drawings for standard parts need not to be creating as they are purchased directly for the IVT test rig.

The motor, belt, UD clutch, and bearings are the standard components used in the IVT test rig. Assembly of the test rig is successfully done with the manufactured parts and standard components. Test and trial is conducted after the assembly, which gives the results for further study.

IV. COSTING OF THE IVT TEST RIG

A. Raw Material Cost:

The total raw material cost as per the individual materials and their corresponding rates per kilogram is Rs 3600 /-

B. Machining Cost:

Operation	Rate (Rs/Hr)	Total Time (Hr)	Total Cost (Rs)
Lathe	80	16	1280
Milling	90	12	1080
Drilling	60	9	540
Job Boring	680	1	680
Total			3580

Table 2: Machining Cost

C. Miscellaneous Costs:

Operation	Cost (Rs)
Gas Cutter	300
Sawing	160
Fabrication	500
Assembly	600
Total	1560

Table 3: Miscellaneous Cost

D. Cost of Purchased Parts:

Sr. No.	Description	Qty.	Cost
1	Motor	01	1450
2	Belt	01	210
3	Grub Screw	07	30
4	Bearings	04	380
5	UD Clutch CSK-15/CSK-20	-	720

Table 4: Cost of Purchased Parts

The cost of purchased parts = Rs 2790 /-

E. Total Cost:

The total cost of the IVT test rig is the addition of all the costs mentioned above.

Total Cost = Raw Material Cost + Machining Cost + Miscellaneous Cost + Cost of Purchased Parts + Overheads
= Rs 13530

Hence the total cost of the machine is Rs 13530.

V. FUTURE SCOPE OF IVT PROJECT

The following points explains the future scope of the infinitely variable transmission system -

1) System design as to linkage kinematics

2) Design and geometrical derivations of the mass profile.
3) Design and development of yoke mechanism and mass linkages.
4) Selection and geometrical profile of cam and intermediate shaft.
5) Selection and design of uni-directional clutches.
6) Selection of motor drive transmission.
7) Mechanical Design: This part includes the design and development of linkages, selection of suitable drive motor, strength analysis of various components under the given system of forces.

VI. Further Modifications

The following modifications can be done for the further improvements -

1) Casing can be made for proper lubrications
2) Mass weight can be increased to increase torque
3) Vehicle can be made by application of chassis and wheels
4) Needle roller bearing can be used on cams to reduce friction

VII. Applications of IVT

The following are the applications of the Infinitely Variable Transmission system -

1) Light cars
2) Golf cars
3) Recreational vehicle
4) Gocarts

VIII. Conclusion

The work proceeded as per the action plan mentioned in the above discussion. Design and drawings for the components of infinitely variable transmission system made easy for manufacturing and assembly of the test rig. This study helps to optimize the recourses like time, money, machines and man power. It makes the budget for IVT test rig is under allowable limit and the manufacturing & assembly within a time limit.

Further, the test and trials has been taken on the test rig. The infinitely variable transmission system test rig ran smoothly while the testing. This modified infinitely variable transmission design easily meets the design requirements for construction and testing of the transmission.

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