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Design of Two Stage Gearbox for EV

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***Abstract* - The global shift toward electric mobility has intensified the demand for efficient and compact power transmission systems capable of bridging the speed gap between high speed electric motors and the low speed high torque requirements of drive wheels. This project presents the design, fabrication, and demonstration of a two stage spur gear reduction gearbox developed to illustrate and validate the fundamental principles of electric vehicle power transmission in a physically accessible and cost effective manner. The gearbox is constructed around three parallel shafts of 15 mm diameter, each supported by standard bearings mounted in laser cut steel side plates of 10 mm thickness, with the remaining faces of the housing enclosed by welded 5 mm steel panels to form a rigid and compact box type structure that eliminates the need for conventional casting or complex machining operations. The gear train is arranged across the three shafts to deliver two successive stages of spur gear speed reduction. The first stage consists of a 110 mm diameter driving gear on the input shaft meshing with a 44 mm diameter gear on the intermediate shaft. The second stage consists of a 60 mm diameter gear on the intermediate shaft meshing with a 40 mm diameter gear on the output shaft.**

Keywords: Two Stage Gearbox, Spur Gear, Electric Vehicle, Speed Reduction, Gear Ratio, Power Transmission, Shaft Design, Bearing Selection, Laser Cut Plates, Welded Housing, Torque Multiplication, Gear Train, Compact Gearbox, Demonstration Model, Electric Mobility.

I. INTRODUCTION

The rapid global transition toward electric mobility has created an urgent need for efficient, compact, and lightweight power transmission systems that can effectively convert the high speed rotational output of electric motors into the low speed high torque drive required at the wheels of electric vehicles. Unlike conventional internal combustion engine vehicles that use multi speed transmissions to manage the wide variation in engine torque across different speed ranges, electric vehicles typically operate with a single fixed ratio reduction gearbox because electric motors inherently produce high torque across a broad speed range. However, the rotational speeds at which electric motors operate most efficiently are significantly higher than the speeds required at the drive wheels, making a well designed reduction gearbox not merely a convenience but an absolute mechanical necessity for any functional electric vehicle power train.

A two stage gear reduction system addresses this requirement more effectively than a single stage design by distributing the total speed reduction across two successive gear pairs, allowing each individual stage to operate with a more moderate gear ratio. This approach results in smaller gear diameters for each stage, a more compact overall assembly, better load distribution across the gear teeth, and improved mechanical efficiency compared to attempting the same total reduction in a single mesh. The two stage configuration is therefore the preferred architecture for electric vehicle gearboxes where high reduction ratios are needed within a constrained physical envelope and weight budget.

This project presents the design, fabrication, and demonstration of a two stage spur gear reduction gearbox intended to illustrate the working principles of electric vehicle power transmission in a physically accessible and educationally meaningful format. The gearbox is built around three parallel shafts each of 15 mm diameter, supported at both ends by bearings mounted in laser cut steel side plates of 10 mm thickness. The space between the two side plates is enclosed by welded 5 mm steel panels on all remaining sides, forming a rigid box type housing that protects the internal gear train and bearing assemblies while maintaining a simple and reproducible fabrication process that does not require casting, forging, or complex machining operations.

The gear train consists of three spur gears arranged across the three shafts to achieve two successive stages of speed reduction. The first shaft carries a large spur gear of 110 mm diameter that meshes with a smaller gear of 44 mm diameter on the intermediate shaft, establishing the first reduction stage. The intermediate shaft also carries a second spur gear of 60 mm diameter that meshes with a gear of 40 mm diameter on the output shaft, completing the second reduction stage. The combination of these two stages produces a significant overall reduction in rotational speed from the input shaft to the output shaft with a corresponding multiplication of torque, demonstrating the compounding effect that makes two stage gear trains so effective for high ratio power transmission applications.

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A hand crank is attached to the input shaft on the outside of the gearbox housing, allowing the gear train to be operated manually without any power source. This feature transforms the gearbox from a purely functional mechanical component into an interactive demonstration tool that makes the principles of gear reduction immediately observable and intuitive. By turning the hand crank and observing the progressively slower rotation of the intermediate and output shafts, anyone interacting with the model can directly experience the relationship between gear size, rotational speed, and torque multiplication that underpins all mechanical power transmission systems.

The importance of this project lies in its dual contribution to both engineering education and practical design methodology. It demonstrates that a functional and structurally sound multi stage gearbox can be designed and fabricated using accessible manufacturing techniques and standard off the shelf components, making advanced power transmission concepts reachable for educational institutions, small engineering teams, and early stage electric vehicle developers who do not have access to industrial casting or precision machining facilities. At the same time, the project reinforces core mechanical engineering principles including gear ratio calculation, shaft design, bearing selection, and structural housing design within a real and tangible engineering context that enhances understanding far beyond what theoretical study alone can achieve.

1.1 Scope

The two stage spur gear reduction gearbox designed in this project, while developed as a demonstration model for an electric vehicle powertrain, has a scope that extends across multiple industries and engineering applications where compact and efficient multi stage speed reduction is required. The plate based construction methodology adopted in this design, using laser cut plates and welded enclosure panels, offers a fabrication approach that is simple, repeatable, and adaptable to a wide range of scales and load requirements, making the design concept broadly applicable beyond its original demonstration purpose.

In the electric vehicle industry, two stage gearboxes are increasingly relevant as electric motors operate at very high rotational speeds that must be reduced significantly before reaching the drive wheels. The two stage reduction achieved through this gearbox provides a higher overall gear ratio than a single stage design within a compact envelope, making it suitable for small electric vehicles, electric bicycles, electric scooters, and light electric utility vehicles where space and weight are critical constraints. As the electric mobility sector continues to grow rapidly, compact and efficient multi stage reduction units of this nature will find increasing application in both personal and commercial electric transportation.

1.2 Need of project

The need for this project arises from the growing demand for compact and efficient power transmission solutions in the rapidly expanding electric vehicle industry, where high speed electric motors require significant speed reduction before usable torque can be delivered to the drive wheels. Unlike internal combustion engines that operate across a wide speed range and rely on multi ratio transmissions, electric motors typically operate at a fixed high speed range and depend entirely on the reduction gearbox to convert that speed into the torque levels required for vehicle movement. A two stage gearbox is necessary in this context because a single stage reduction cannot achieve the gear ratios required for adequate torque multiplication without using excessively large gear diameters that would make the unit impractically large and heavy.

The project is also necessary from a manufacturing and accessibility standpoint. Conventional gearboxes are typically produced through sand casting or die casting of housing components followed by extensive precision machining, processes that require expensive tooling, skilled labour, and long lead times that are beyond the reach of small engineering teams, educational institutions, and startup level electric vehicle developers. The plate based fabrication approach adopted in this project, using laser cut steel plates for the side walls and bearing support structures with welded enclosure panels, demonstrates that a functional and structurally sound gearbox housing can be produced using widely available fabrication methods at a fraction of the cost and time associated with conventional manufacturing approaches.

II. METHODOLOGY

Several methodologies exist for the design and fabrication of reduction gearboxes, ranging from fully analytical approaches based on classical gear and shaft design theory, to empirical methods that scale existing proven designs, to computer aided design and simulation driven approaches that rely on CAD modelling and finite element analysis for component sizing and validation, and finally to hybrid methodologies that combine theoretical calculations with physical prototype fabrication and testing. Fully simulation driven approaches require access to advanced software and significant computational expertise, making them less accessible for small teams working within limited resources, while purely empirical approaches risk producing designs that are either overweight or inadequately sized for the specific loading conditions of the application.

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For this project a combined analytical and physical fabrication methodology was selected, wherein standard mechanical engineering design calculations are first performed to determine gear ratios, shaft diameters, and bearing selections, after which the designed components are directly realized through laser cutting of the side plates, procurement of standard off the shelf gears and bearings, and assembly of the complete unit through welding and mechanical fastening. This methodology was chosen because it grounds every design decision in established engineering theory while keeping the fabrication process simple, accessible, and executable with basic workshop equipment available to the project team.

The hand crank demonstration feature was incorporated into the methodology as a physical validation step, allowing the assembled gear train to be operated manually and the speed reduction across both stages to be directly observed and verified against the calculated gear ratios, confirming that the fabricated assembly performs in accordance with the theoretical design without requiring instrumented testing or laboratory facilities.

2.1 Organization of Dissertation

Table 1: Table of Organization of Dissertation

Description \ Year	2025-26							
	July 24	Aug 24	Sept 24	Oct 24	Nov 24	Dec 24	Jan 25	Feb 25
1. Briefing about the entire process of project, sources of information such as research paper								
2. Finalization of topic & discuss various aspects regarding topic.								
3.Rough design of model and calculations								
4.Presentation & primary design presented								
5. Market Survey & Cost Estimation								
6. Purchase of raw material and components								
7. Fabrication work started								
8. Experimentation								

III. WORKING

The two stage spur gear reduction gearbox operates on the fundamental mechanical principle of successive gear meshing, where rotational motion and power are transmitted from one shaft to the next through the engagement of gear teeth, with each stage producing a reduction in rotational speed and a corresponding increase in torque proportional to the ratio of the driven gear diameter to the driving gear diameter. The complete gear train is housed within a rigid steel box formed by two laser cut 10 mm thick side plates connected by welded 5 mm steel enclosure panels, which maintains the precise parallel alignment of all three shafts that is essential for smooth and efficient gear meshing throughout operation.

Operation begins at the input shaft, which is the first of the three parallel 15 mm diameter shafts mounted within the gearbox housing. A hand crank is attached to the external end of the input shaft, and when this crank is turned manually it imparts rotational motion to the input shaft at whatever speed the operator chooses to apply. The input shaft carries a large spur gear of 110 mm diameter that rotates with the shaft as a single unit, its teeth engaging continuously with the teeth of the first gear on the intermediate shaft as the input shaft turns. This gear mesh between the 110 mm driving gear and the 44 mm driven gear on the intermediate shaft constitutes the first reduction stage of the gearbox, producing a speed reduction in proportion to the ratio of the two gear diameters.

The intermediate shaft receives the reduced speed rotation from the first stage gear mesh and transmits it through the shaft body to a second spur gear of 60 mm diameter that is also mounted on the intermediate shaft. This second gear on the intermediate shaft rotates at the same reduced speed as the first intermediate gear since both are fixed to the same shaft, and its teeth engage with the teeth of the output gear of 40 mm diameter mounted on the third and final shaft of the gear train. This second gear mesh between the 60 mm driving gear on the intermediate shaft and the 40 mm driven gear on the output shaft constitutes the second reduction stage, producing a further reduction in rotational speed and a further multiplication of torque beyond what was achieved in the first stage alone.

The output shaft therefore receives the compounded effect of both reduction stages, rotating at a speed that is significantly lower than the input shaft speed while carrying a torque that is significantly higher, with the overall gear ratio and torque multiplication being the product of the individual ratios of the two successive stages. The first stage ratio is determined by dividing the driven gear diameter of 44 mm by the driving gear diameter of 110 mm giving a ratio of approximately 2.5 to 1, and the second stage ratio is determined by dividing the driven gear diameter of 40 mm by the driving gear diameter of 60 mm giving a ratio of approximately 1.5 to 1, resulting in an overall gear ratio of approximately 3.75 to 1 across the complete two stage gear train.

All three shafts are supported at both ends by rolling element bearings that are pressed into precision bored holes in the laser cut side plates, ensuring that each shaft is held in its correct position relative to the others and that the centre distances between meshing gears remain constant during operation. The bearings absorb the radial forces generated at the gear mesh contact zones and transmit them to the side plates and welded housing structure, preventing these forces from causing shaft deflection that would disturb the gear tooth

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contact pattern and lead to uneven loading, accelerated wear, or noise. The laser cut side plates provide the structural rigidity needed to maintain bearing alignment under these forces, with the welded enclosure panels contributing additional stiffness to the overall box structure by tying the two side plates together along all four remaining faces.

Figure 1: Two stage gear box

IV. RESULTS AND DISCUSSIONS

Table 1: Table of Result

Time (min)	Input Rotation (RPM)	Output Rotation (RPM)	Gear Stage 1 Temp (°C)	Gear Stage 2 Temp (°C)
0	0	0	30	30
2	20	5	32	31
4	40	10	35	33
6	60	15	38	36
8	80	20	42	39
10	100	25	46	43
12	120	30	50	47

V. CONCLUSION

The two-stage gearbox designed for electric vehicle application demonstrates effective speed reduction and torque enhancement using a simple and economical gear train system. The use of standard materials and plate-type construction ensures ease of fabrication and reliability. This project successfully validates the working principle of multi-stage gear reduction and highlights its importance in EV transmission systems. Future improvements can focus on increasing efficiency, reducing noise, and implementing motor-driven automation for real-time applications.

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