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ROTARY POWER STEERING SYSTEM

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***Abstract**: Demands for including more functions such as haptic guiding in power steering systems in road vehicles have increased with requirements on new active safety and comfort systems. Active safety systems, which have been proven to have a positive effect on overall vehicle safety, refer to systems that give the driver assistance in more and less critical situations to avoid accidents. Active safety features are going to play an increasingly important roll in future safety strategies; therefore, it is essential that sub systems in road vehicles, such as power steering systems, are adjusted to meet new demands. The traditional Rotary Power Assisted Steering, HPAS, system, cannot meet these new demands, due to the control unit's pure hydro-mechanical solution. The Active Pinion concept presented in this thesis is a novel concept for controlling the steering wheel torque in future active safety and comfort applications. The concept, which can be seen as a modular add-on added to a traditional HPAS system, introduces an additional degree of freedom to the control unit. Different control modes used to meet the demands of new functionality applications are presented and tested in a hardware-in-the-loop test rig. This paper also covers various aspects of Rotary power assisted steering systems in road vehicles. Power steering is viewed as a dynamic system and is investigated with linear and non-linear modeling techniques. The valve design in terms of area gradient is essential for the function of the HPAS system; therefore, a method involving optimization has been developed to determine the valve characteristic. The method uses static measurements as a base for calculation and optimization; the results are used in both linear and the nonlinear models. With the help of the linear model, relevant transfer functions and the underlying control structure of the power steering system have been derived and analyzed. The non-linear model has been used in concept validation of the Active Pinion. Apart from concept validation and controller design of the active pinion, the models have been proven effective to explain dynamic phenomena related to HPAS systems, such as the chattering phenomena and Rotary lag.*

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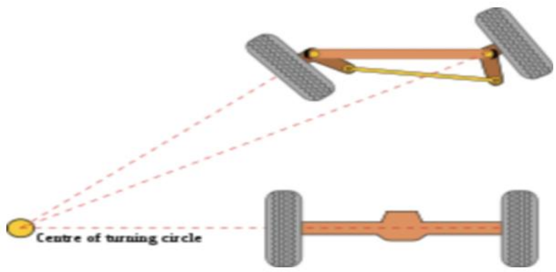
I. INTRODUCTION

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship, boat) or vehicle (car, motorcycle, bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches (and also known as 'points' in British English) provide the steering function.

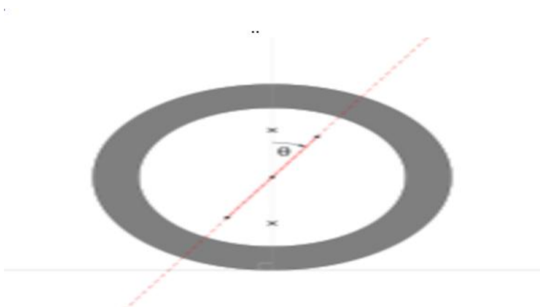
Part of car steering mechanism: tie rod, steering arm, king pin axis (using ball joints). The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear–wheel steering. Tracked vehicles such as bulldozers and tanks usually employ **differential steering** — that is, the tracks are made to move at different speeds or even in opposite directions, using clutches and brakes, to bring about a change of course or direction

Wheeled vehicle steering

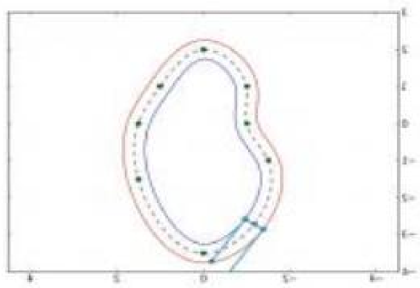
Basic geometry



Ackermann steering geometry



Caster angle θ indicates kingpin pivot line and gray area indicates vehicle's tire with the wheel moving from right to left. A positive caster angle aids in directional stability, as the wheel tends to trail, but a large angle makes steering more difficult.



Curves described by the rear wheels of a conventional automobile. While the vehicle moves with a constant speed it's inner and outer rear wheels don't.

II REVIEW OF LITERATURE

Safety is a predominant issues today; therefore, a great deal of research concerns safety issues. Safety in cars can be divided into two categories, passive and active safety. Passive safety refers to functions that help mitigate the severity of accidents when such as seat belts, airbag etc. Active safety features refer to functions that assist the driver to avoid an accident such as anti-lock brakes, traction control [1], and active yaw control. Wilfert proposed a definition of

passive and active safety where he also suggested a classification [2]. A more recent work concerning active safety was performed by E. Donges, [3], who divides active safety functions and driver assisting functions into four levels, Information, Warning, Vehicle Dynamic Control and Action Recommendation.

The effect of active safety functions has been proven successful for overall vehicle

safety. A. Tingvall et al. stated that the dynamic yaw control system increases safety up to 38%, especially on winter road conditions [4]. Several other investigations have reached similar conclusions, see for instance [5–8]. The active yaw control system was the first active safety system on the market, where the potential for the systems was visible. New systems are entering the market such as Adaptive Cruise Control, ACC, which is a system that helps the driver in the longitudinal control of the car, thereby keeping a safe distance to the vehicles ahead, [9].

The systems mentioned above use the brakes, the drive-train or a combination of both to enable active safety functions. Power steering systems have not been involved in active safety system with the exception of the newly introduced variable ration power steering system, Active steering, which is described by P. K¨ohn, [10, 11]. When implemented in the vehicle, the system does not effect active safety but could be used for active yaw control. Research concerning dynamic yaw control utilizing the power steering system has been carried out by J Ackermann.

Rotary Power Steering System Design in Road Vehicles:

Active safety features are going to play a more important roll in future safety strategies; therefore, it is essential that vehicle sub systems are adjusted to meet new demands. Next generation active safety might also involve the steering system in guiding the driver out of a safety critical situation such as Lane Keeping Aid, LKA. LKA systems help the driver keep the lateral position of the vehicle, thereby reducing the risk for road departure accidents; this can be compared to the ACC system, which is a longitudinal control. The LKA system has been investigated by different researchers and with different actuation. Franke et al. enable the system by adding a correction to the driver's input steering, [15]; whereas Pohl and Ekmark added a guiding torque to the steering wheel, thereby enabling a haptic communication with the driver, [16]. The last example can be seen as an action recommendation that guides the driver out of a safety critical situation. There are also other safety functions that can utilize enhanced functionality in the steering system, which will be discussed further in the thesis.

There are a number of feasible concepts to enable steering intervention ranging from additional actuators applying torque to the steering column to Electric Power Assisted Steering, EPAS, systems, [17]. The latter has recently entered the market, mainly in order to meet future requirements on emission and fuel consumption, as the efficiency of traditional Rotary power assisted steering, HPAS, systems, especially for highway driving, is quite low. However, unless 42V technology is available, the application of EPAS systems will be restricted to smaller and medium sized vehicles, [18]. This thesis concerns Rotary actuator design in HPAS systems to support and enable active safety functions that demand haptic communication with the driver.

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Power steering systems are probably the most used servo_ system by the common man, even though most users never give it a second thought. The first power steering unit was invented by Francis W. Davis in the mid 1920's [19], but was not introduced in passenger cars until 1951. A figure of the system can be seen in Figure 2.1. This system was of the type: ball and nut, and is still in use in vehicles with higher steering forces, typically larger trucks.

The predominant system used patents by Francis W. Davis [20]. today is of the type: rack and
pinion, which was introduced in the late 1960's in medium performance sports cars. There are several different power assisted steering, PAS, solutions for passenger cars on the market today. The most common is the rack and pinion solution with a constant flow controlled pump, Rotary Power Assisted Steering – HPAS system. More recently an Electric Power Assisted Steering, EPAS system, was introduced in smaller cars.

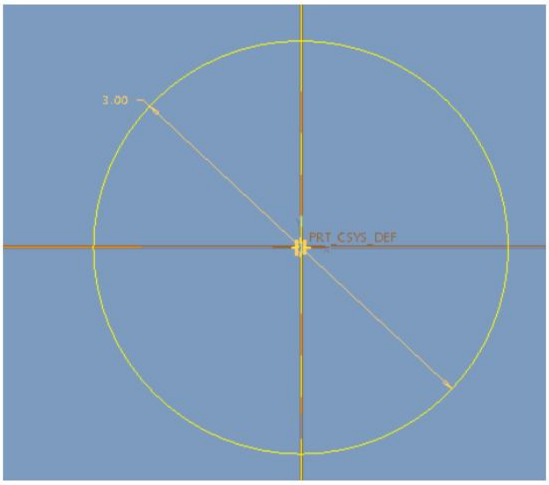
III Design

Engineering Design

Creon Elements/Pro offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free-form surface tools.

SKETCH USED IN MAKING POWER STEERING SYSTEM:



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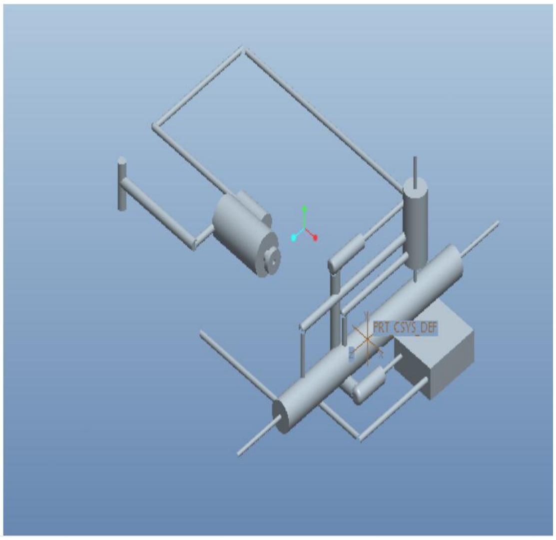
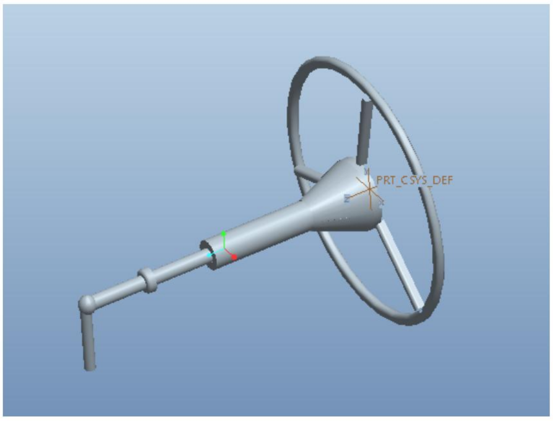
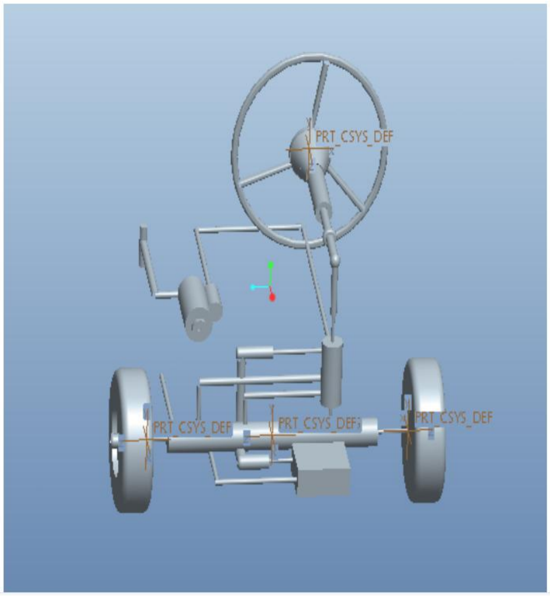
COMPLETE DESIGN OF A STEERING MECHANISM:



COMPLETE DESIGN OF STEERING WHEEL:



COMPLETE DESIGN OF A STEERING SYSTEM AFTER ASSEMBLY:



Speed Sensitive Steering

An outgrowth of power steering is speed sensitive steering, where the steering is heavily assisted at low speed and lightly assisted at high speed. The auto makers perceive that motorists might need to make large steering inputs while manoeuvring for parking, but not while traveling at high speed. The first vehicle with this feature was the Citroën SM with its Diravi

layout, although rather than altering the amount of assistance as in modern power steering systems, it altered the pressure on a centering cam which made the steering wheel try to "spring" back to the straight-ahead position. Modern speed-sensitive power steering systems reduce the

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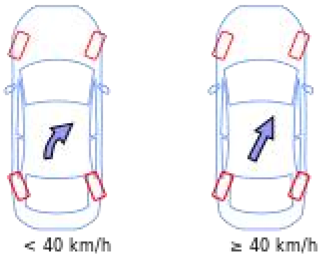
mechanical or electrical assistance as the vehicle speed increases, giving a more direct feel. This feature is gradually becoming more common.

Four-wheel steering



Speed-dependent four-wheel steering.

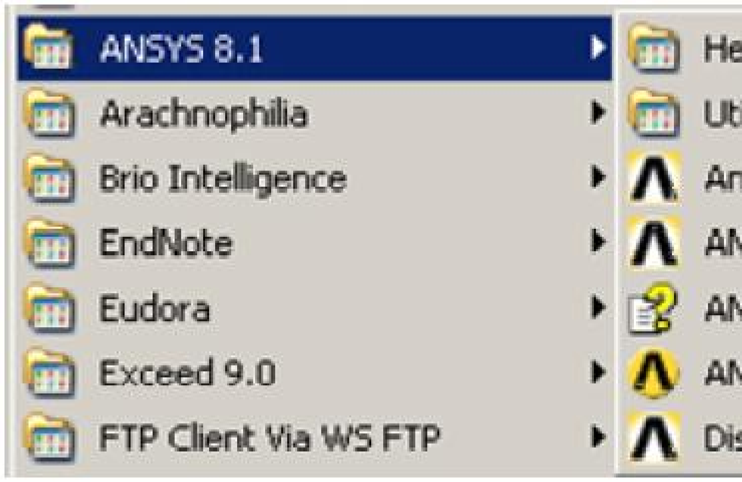
Four-wheel steering (or all-wheel steering) is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed.

Early example of four-wheel steering. four-wheel steering.

IV ANALYSIS

Starting ANSYS:

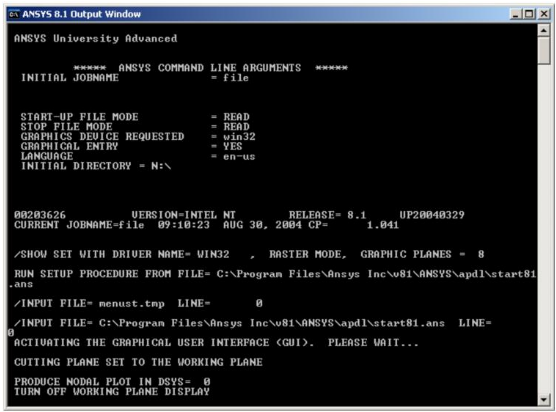
The ANSYS graphical user interface can be started by selecting the ANSYS icon located in the ANSYS 8.1 folder.



Selecting the ANSYS icon will take you directly to the graphical user interface.

ANSYS Graphical User Interface:

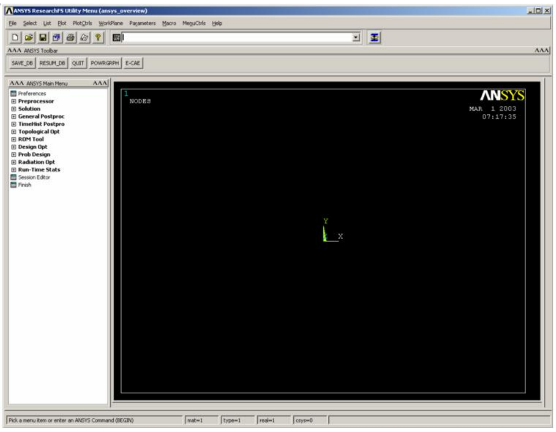
After starting ANSYS, two windows will appear. The first is the ANSYS 8.1 Output Window:



This window displays a listing of every command that ANSYS executes. If you encounter problems, this is a good place to look to see what ANSYS is doing or has done. This is one location where you will find all of the warnings and error messages that appear and the command that generated the warning/error. The second window is the ANSYS Research FS graphical user interface. This is divided into 4 sections (shown on next page):

1. ANSYS Utility Menu
2. ANSYS Toolbar Menu
3. ANSYS Main Menu
4. Display window

Each section will be discussed in further detail below.

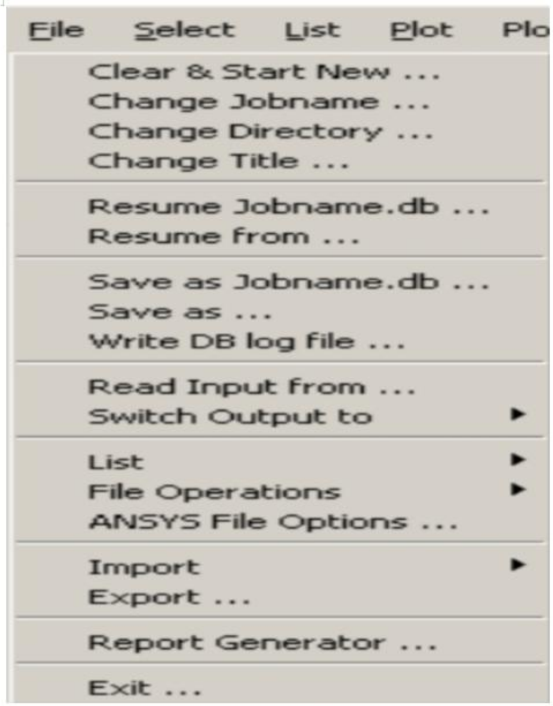


Within this menu, you can perform file operations, list and plot items, and change display options.

Fil

File Drop-down Menu

The File drop-down menu includes the options to clear the database, change, resume, and save the current model.



Clear and Start New deletes the current database. It does not clear the log or error files.

Change Job name changes the name of the database and associated files.

The next time you save, it will write everything to the current job name. It will not delete the previous job name or associated files.

Note: unless you check the box for New log and error files, it will continue

to write to the current log and error files.

Change Directory allows you to switch directories where the files are being saved.

Resume Job name.db and Resume from allows you to open a model that has

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already been saved. Note: If you resume a file, ANSYS does not automatically switch the current job name to the name of the file you resumed from. Change the job name otherwise you may write over another model.

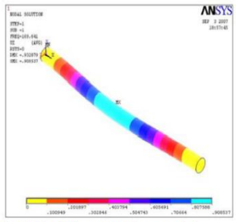

Figure 7. The displacement rate of composite shaft in z-direction at first mode

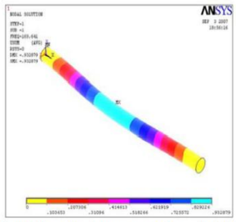

Figure 8. The total displacement contour of composite shaft at first mode

Table 2. Natural frequencies of composite drive shaft

Frequency Number	Frequency (Hz)
1	169.64
2	182.67
3	226.73
4	255.98
5	278.44

V CONCLUSION

In this paper a one-piece composite drive shaft is considered to be replaced a two-piece steel drive shaft. Its design procedure is studied and along with finite element analysis some important parameter are obtained.

The composite drive shaft made up of high modulus carbon / epoxy multilayered composites has been designed.

The replacement of composite materials has resulted in considerable amount of weight reduction about 72% when compared to conventional steel shaft. Also, the results reveal that the orientation of fibers has great influence on the dynamic characteristics of the composite shafts.

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