## II. GENERAL AUDIENCE PROJECT SUMMARY

Increased concern for sustainability has led to a dramatic increase in demand for more efficient and environmentally friendly motor vehicles. Much research has been done to determine where efficiency can be increased and the environmental impact can be minimized. One impactful and feasible option is the implementation of a spring based starter. Batteries are great at storing energy, but are difficult to quickly retrieve energy from. Large cables and oversized batteries are required to access the energy at a rate necessary to start an internal combustion engine used in conventional automobiles. Springs are not as good at storing the energy, but have the capacity to release energy at a high rate. The ability to release all of their stored energy in a short amount of time make springs a logical candidate for starting motor vehicles. The spring starter could be charged from the running engine, or it could be wound by hand in emergency situations. The spring-based starter is not intended to fully eliminate the vehicle's battery because a battery is still needed run other devices when the car is not running, such as the lights and radio. The spring starter may allow the battery size to be greatly reduced along with the cables connecting to the battery. Additionally, energy losses see during the conversion of chemical to electrical mechanical will be reduced because there is no conversion of energy. By implementing a spring starter in an automobile, the environmental impact from the lead-acid batteries is reduced and the efficiency is increased. This project will focus on researching the feasibility of implementing a spring-based starter in a production vehicle. In addition, concepts of mechanism to charge the spring from a running engine will be designed and prototyped.

## III. PROPOSED THESIS TITLE AND PROPOSED ABSTRACT

**Title:**

Implementation of a Spring-based Starter System into Production Vehicles

**Abstract:**

Companies are striving to make more efficient and environmentally friendly automobiles. Two areas of inefficiencies are unnecessary weight and the continual conversion of chemical to electrical mechanical energy. Researchers are exploring all areas of vehicles to reduce these inefficiencies [1]. The electric based starter on motor vehicles draws current from a large lead-acid battery that is subsequently recharged by the alternator. The battery is then used to run all the ancillary devices while the vehicle is running [1]. A spring based starter is an appealing alternative starting mechanism. Springs have a low energy density of about 0.3 kJ/kg [2] when compared to the traditional lead-acid battery used in motor vehicles with an energy density of approximately 140 kJ/kg [3]. However, springs have a high power density, meaning they are able to release their power quickly. Additionally there is much less efficiency loss since there is no chemical to electrical to mechanical energy conversion. This makes springs an appealing alternative to batteries for starting a vehicle. The spring starter would greatly reduce the size of the battery necessary in a vehicle. A significant amount a research has been done in developing a working starting mechanism. The focus of this project will be on the implementation of the spring starter in a motor vehicle. While a car is running, a battery is required; however, it is unclear how much amperage is being drawn from the ancillary equipment on a vehicle. The proposed research will focus on what is require of a battery in a car and what size battery would be needed in a vehicle with the spring starter implemented. In order to implement the device into

a motor vehicle a mechanism to recharge the spring is required. Along with the research, concepts of the charging mechanism will be prototyped and tested.

## IV. PROJECT DESCRIPTION

Efficiency and sustainability are currently two of the primary initiatives of automobile companies [4]. With the threat of global warming, depletion of natural resources, and the constant concern for pollution, people are looking for ways to reduce their carbon footprint. Lead-acid batteries are used in most starting systems of motor vehicles, and if not disposed of properly are of great environmental concern [5]. In addition, when it comes to releasing their energy, batteries are not the best means. They are good at storing energy, but inefficient at quickly releasing it. Naturally, reducing or eliminating the battery on a vehicle is an attractive option to reducing environmental impact and increasing efficiency.

Environmental pollution from exhaust gases and lead in car and truck batteries are long-term environmental and health hazards. As of 2000, automotive battery production processes accounted for the release or transfer of approximately 71,000 metric tons of lead [6]. Batteries are of huge environmental concern when not disposed of properly. A law was signed on May 17, 1990 making it illegal to dispose of lead-acid batteries is the trash. Lead and acid from the batteries eventually leaks out of the batteries and into the groundwater and soil. The chemicals in batteries have serious effects on human health. Low levels of lead exposure can impair a child's mental development. Additionally, the lead is a neurotoxin that can be harmful to kidneys and the reproductive system [7].

Reducing the size of the lead-acid battery in motor vehicles can be done with the implementation of a spring-based starter. Elastic energy has long been used in many applications. There are current spring starters available on small lawn mowers [8] and remote power generators [9]. However, there has not been a spring-based starter implemented on a motor vehicle. Implementation of a spring starter would greatly reduce the size of the required battery on a vehicle, eliminate the amount of battery disposal in the country, and could have a lower weight than the traditional starting system. The main obstacle that needs to be overcome in implementing a spring-based starter is designing a mechanism to capture some energy to recharge the spring for restarting the car. Designs for the starting mechanism have already been designed and prototyped.

The primary feature of the mechanical starter is the use of a spring rather than a battery to store energy. Initial concepts were designed to be packaged on a Yamaha XJ600s motorcycle. To determine the size of the spring for the starting system, the starting requirements of the motorcycle had to be found. A typical internal combustion engine requires a minimum rotational speed of 100-200 rpm [10]. However, the torque required varies from engine to engine. Experimental techniques were performed to determine the torque constant of the motorcycles electric starter motor known [11], making it possible to estimate the torque transmitted at the starter shaft by measuring current draw during a starting cycle. With this information, the required characteristics of the spring could be determined. The spring can take many geometric forms. A spring formed through tensile bands most efficiently utilizes the material as the entire section is stressed at the same level [12]. A sketch of the spring-based starter concept is shown in Fig. 1. One end of the spring is deflected by a worm gear drive, storing and locking energy in the spring. The other end of the spring is coupled to the engine shaft via transmission gears. A latching mechanism is placed between the spring and the transmission gears and is engaged when necessary to prevent the system from releasing energy. A one-way or overrunning clutch is mounted to the final gear of the transmission, such that the system is coupled to the engine

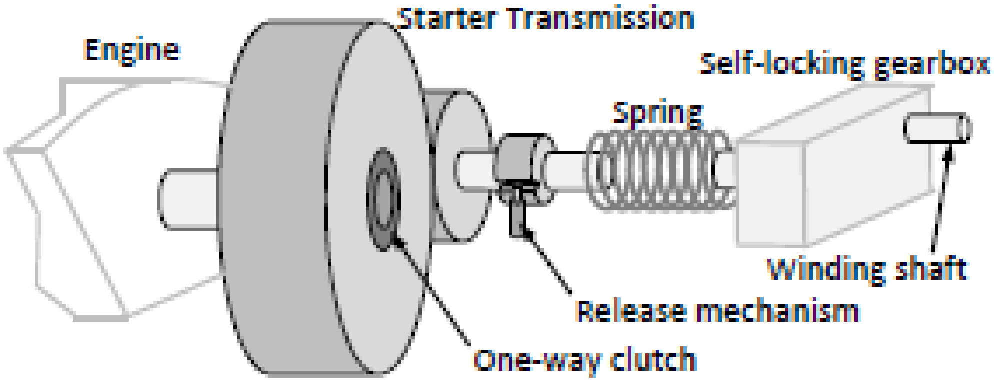


**Figure 1: Spring-based starter concept**

during the starting cycle and decoupled during normal engine operation [1]. To start the engine the latching mechanism is released and the energy from the spring is rapidly released. The spring is then recharged using either a small electric motor and battery or by siphoning some energy from the engine.

A functional prototype was generated of the spring based starter. The 3.5 lb. spring was optimized through spring design equations and experimental data. The system was conceived as a separated unit, and can be seen in Fig. 2. Ideally, this starter system would be packaged on the

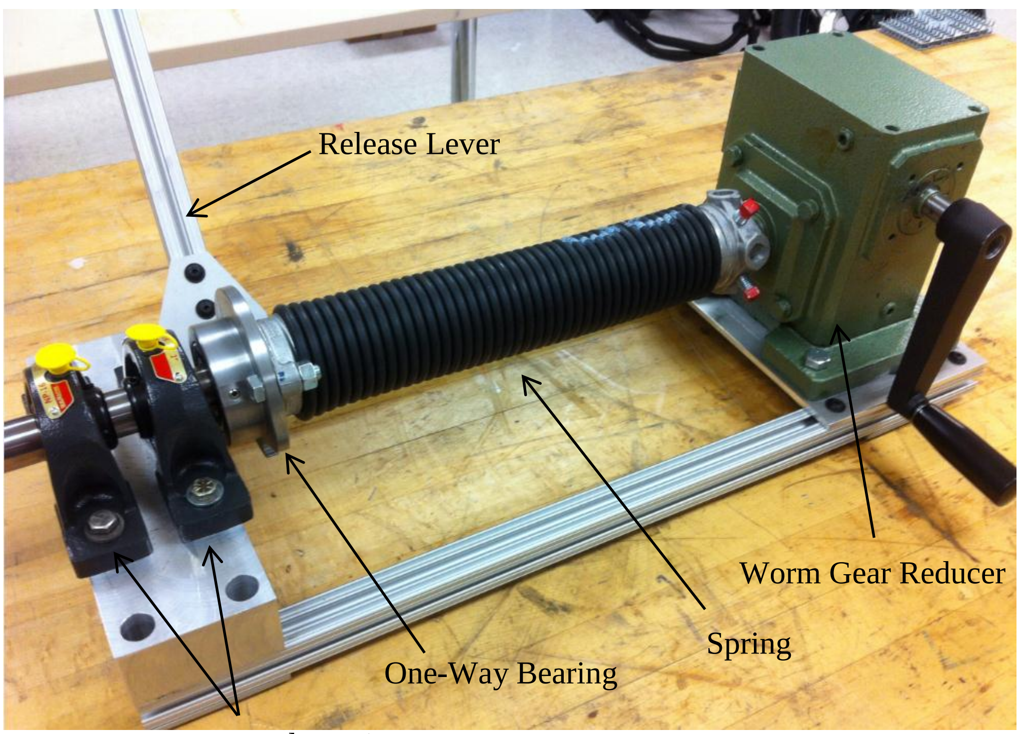


**Figure 2: Physical functional prototype of standalone spring starter.**

motorcycle. With limited space on the motorcycle, a new starter transmission and clutch assembly would need to be redesigned. Since that was beyond the scope of functional concept testing, a standalone starter system was the most reasonable to fabricate.

To adapt to a standalone starter, the end of the Yamaha XJ600s crankshaft was modified to accept a shaft from a portable spring starter system. The engine was completely disassembled and the crank shaft was removed and machined to accept an adapter, which will mate with the end of the starter shaft. The crankshaft end adapter is a male 0.5 in hexagonal profile that mates with a socket, which is fastened to the spring starter system shaft. The original end of the crank shaft and a model of the modified end can be seen below in Fig. 3.

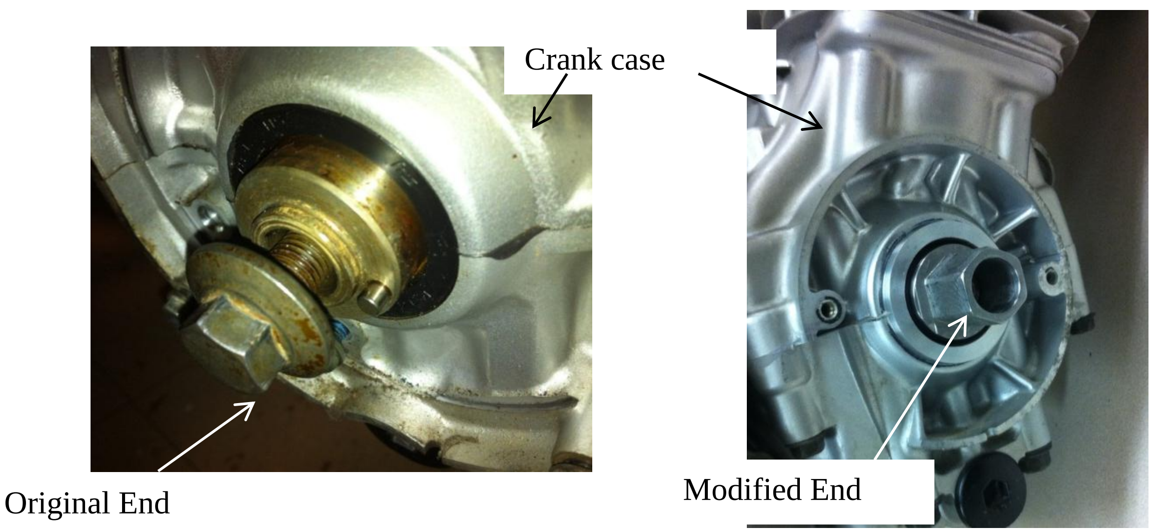


**Figure 3: Crankshaft end modification for mounting the standalone spring starter.**

There has been much research and design of the current spring-based starter prototype. The primary focus of this thesis project is to extend the already designed spring-based starter and implement it into a production vehicle as well as perform feasibility and design investigations. The process for doing so will involve additional background research, conceptual and detailed design, and experimentation. There are key research questions that the project aims to answer and they will be mapped out in the following paragraphs.

**Task 1:** Besides starting, determine how much amperage is required from a 12V automobile battery.

It has been established that automobiles required a battery to run ancillary devices such as the lights and radios. However, it is currently unknown how many amps are being drawn off a running car battery. If the electric starter is removed, the size of the battery can be decreased. The research question that needs to be answered is how big does the battery need to be to run the ancillary devices. In order to answer this question research will be done on the amperage draw from devices around vehicles. In addition, experiments will be conducted on multiple automobiles to determine what size battery is required.

**Task 2:** In large trucks determine the energy required of a battery other than starting.

Similar to small automobiles, trucks require a battery to start and run a diesel engine. However, their batteries can weigh over 100 pounds. Part of this thesis project will aim at determining what is required of the batteries in large trucks. This will be done primarily though researching larger trucks and making models of the devices running off of the battery to determine the amperage draw.

**Task 3:** Assuming the spring weighs 3.5 lbs., determine the full starting system weight.

A main goal of the spring-based starting system is lowering the overall weight of the starting system in a motor vehicle. This leads to better fuel economy and less environmental impact. It is important to know how much the system will weigh before knowing whether the design is worth pursuing. This project will determine the weight of the full starting system by modeling a production version and making weight estimates based on the size and material. From this information it will be determined whether the system weighs more or less than the electric starting system.

**Task 4:** Determine the effort (compared to other manual tasks) that is required to charge the spring by hand.

A spring-based starter has the ability to be wound by hand in case of emergency. A question that will be answered through research and experimentation is how much effort is required to fully charge the spring so it has enough energy to start a vehicle. The effort that needs to be put in to charge by hand may be unrealistic for an average person. This project will aim at answering this big question.

**Task 5:** If a battery is used to slowly charge the spring, determine how much it will weigh.

A possible method of charging the spring is through a small battery and electric motor. This is an alternative to siphoning as small amount of power from the engine to charge the spring. Part of this thesis project will explore this option of slowly charging the spring by means of a battery and determine the required capacity and corresponding weight of the battery.

**Task 6:** Generate mechanism concepts that are able to charge the spring directly from the engine shaft.

A major task in integrating the spring-based starter into a production vehicle is being able to charge the spring through means other than human power or battery. This is an essential aspect that has yet to be looked into at great detail. As a result of this thesis project, working mechanism concepts that are able to charge the spring will be generated. The concepts will focus on not only the ability to charge the spring, but also the feasibility of integrating it into a production vehicle.

## V. TIMELINE:

<u>2014</u>

JANUARY- APRIL Tasks 1 and 2

MAY-AUGUST Co-op and Tasks 3 and 4

FALL TBD Attend required Senior Thesis Workshop

SEPTEMBER- DECEMBER Tasks 5 and 6

<u>2015</u>

JANUARY 31 Complete the *Symposium Registration Form* to register thesis information for the Honors Students Symposium

Thesis Writing

FEBRUARY Thesis Writing

MARCH 20 Oral presentation of thesis at the Honors Students Symposium (HSS15)

APRIL 8 Submit electronic copy all Word documents of the thesis to Ramona Speranza

April 15 Present thesis project at a poster session of the Stander Symposium

**VI. Working Bibliography**


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[12] Carlson, H. (1995) Spring Designer's Handbook, 2/e, SAE International, Warrendale, PA.

## VII. BUDGET

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|---|---|
| • Bench Top Rig Assemblies | $100 |
| • Off-the-Shelf Components for Bench Top Testing | $125 |
| • Machined Components for Bench Top Testing | $75 |
| • Off-the Shelf Components for Prototype | $550 |
| • Machined Components for Prototype | $450 |
| • Components to Optimize Prototype Functionality | $200 |
| Total Budget Requested | $1500 |