Design and Development of Energy Harvesting using Domestic Geyser

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A thesis submitted in partial fulfillment of the requirements for the degree of

MS Design and Manufacturing Engineering

Supervisor

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DEDICATION

To my Beloved Parents,
without whom none of my success
would have been possible

.

&

To my Respected Teachers,
Who acted like compass,
that activated the magnets of Curiosity,
knowledge, and wisdom in me.

ABSTRACT:

Energy harvesting is being done through many techniques. Energy is extracted from various unconventional resources including light, heat, etc. Environmental power generation is another alternative word. This research is basically aimed at such a technique, which is rather new in energy harvesting. Basically, the system has four major parts. A domestic water geyser, steam turbine, generator and an energy storage unit. In this technique, domestic water geyser is used for steam production. It is installed in a steam turbine. The shaft is coupled with the generator which produces energy. The energy is stored in the battery afterwards. The turbine is designed in such a way that it increases the overall efficiency of the system. Water is converted into high-pressured steam. The turbine rotor starts to move due to the high pressure. Since its connected to the generator, it produces electric charge. The system is designed in such a way that the turbine has an outlet orifice which is connected back to the water entry pipe assembled against the geyser. The steam leaves through orifice and enters back through the water-inlet pipe. In this way, less energy is wasted which means that the system efficiency increases. The whole design was first simulated using SolidWorks. These simulations helped in designing a proper steam turbine. The design includes dimensions, energy calculations and material selection. Proper operating points have been found using literature study and Hit-and-trial methodology. In the end, results have been shown and discussed as it is a Simulation-based thesis. Different operating points were established. The goal was to design an industrial-friendly system and to provide a supplemental source of electric power to the common man of the country.

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1 CHAPTER 1: "INTRODUCTION"

The process in which energy is extracted from different sources such as mechanical load, vibrations, temperature gradient and light, etc., and then transformed into small amounts of power is known as Energy Harvesting (EH). The power obtained is usually in nW-mW range[1].

As far as one can remember, energy is the prime factor in driving human life. Be it technology or food, nothing can survive without energy. Conventional sources are primarily used for energy extraction. Energy Harvesting does the opposite. It is a process in which small amounts of energy is collected from unconventional resources like light, heat, vibrations, radio waves, etc., and then used for multiple purposes. It is also termed as environmental power generation. Certain materials, referred to as "smart materials" are developed to respond in unconventional ways by allowing these materials, when exposed to external sources such as sunlight, heat, and vibration, to convert those into electrical energy[2].

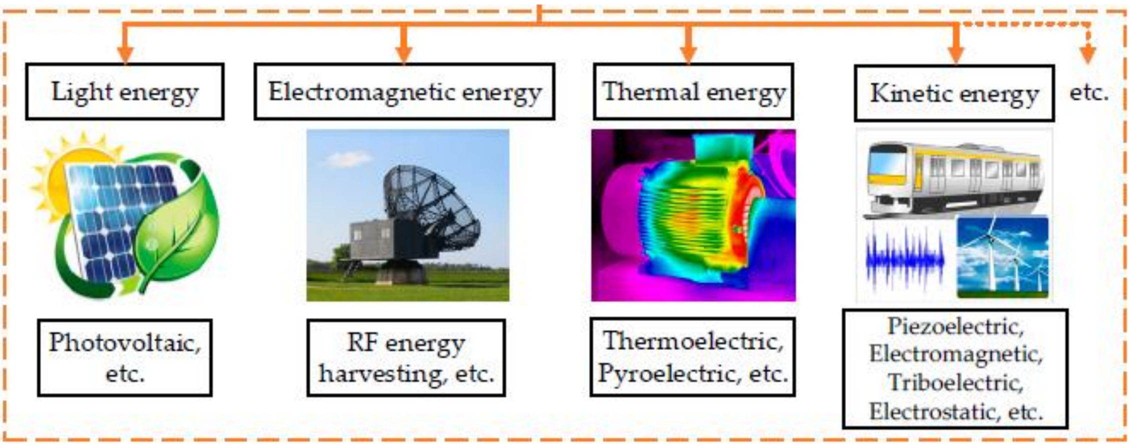

Figure 1 – Energy Harvesting Technologies[3]

The above figure gives a pictorial representation of different harvesting technologies that are currently in work. In mechanical systems, energy losses in energy conversion and transfer occur in the form of friction, heat, deformation, and vibration during operation. Therefore, it is noted that the mechanical efficiency is always lower that 100%[3].

Energy harvesting using Domestic Geysers is another but relatively new technique. It is much more convenient than other techniques being used. It is an application of energy harvesting, power cords, changing batteries, charging batteries, filling fuel tanks, and the like will become unnecessary.

1.1 Research Motivation:

Despite the works being done on energy harvesting, many gaps were found while studying literature. As already discussed, there are many ways through which energy harvesting is done. Energy harvesting through domestic geysers one of them. A major research gap was found when domestic geyser technique was studied. The motive of this research was to design a system that should be eco-friendly, industrial-friendly and easy to install. There goal was to provide common-man with an alternative source of electrical power. Moreover, it was found that the efficiency of existing systems wasn't up to the mark.

The following table gives a bird's eye-view of some techniques used for energy harvesting. It contains power and limitations as well.

Type	**Power density (W/cm^2)**	**Limitations**
Solar	20μ-200m	Light intensity
Thermal	30μ-30m	Thermal difference
RF wave	200p-1m	Distance and RF harmonic
Vibration/PZT	4μ-200μ	Vibration frequency
Vibration/EM	25μ-10m	AC/DC conversion

Table 1 – Comparison of Energy Harvesting Techniques[4]

1.2 Research Objectives:

1. Design a simple and cost-efficient steam-driven Energy harvesting system using a domestic water geyser as the source for steam production.
2. The intent of research is to render the system as industrial friendly as possible.
3. It can be commercialized with maximum readiness.
4. The goal of research is to facilitate the citizens with average or below average income with a constantly available supplemental source of electrical power to compensate with the ever-increasing cost of electricity in Pakistan at large.

1.3 Research Scope:

This research is limited to the development of an energy harvesting using domestic geyser as a source of steam production. There are two major products in this research:

1. Domestic Geyser.
2. Steam Turbine.

Domestic geyser is used to produce the steam and is integrated with steam turbine in such a way that the turbine rotates. A generator is connected that produces electric charge which is then stored into the battery or any other source.

Step-wise procedure performed in this research are as follow:

1. Selection of domestic geyser, steam valves, batteries.
2. Selection of proper design of Steam Turbine.
3. Operating points were decided.
4. Making of simulations and designs.
5. Checking validity for energy production.
6. Setting-up experimental design.
7. Comparison of results i.e., analytical, simulation and experimental results.
8. Energy production.

1.4 Research Methodology:

Domestic geyser was selected first. It was done through extensive literature study. The next most important task wo to design a steam turbine. This is the core component of this research. Simulations were done in order to select the proper design for the experimental setup. Operating procedures were determined after research and hit-and-trial method. Experimental setup was designed then. In the end, results were compiled and compared. The final part was electricity generation.

To achieve the desired goals, a detailed introduction is given first followed by a detailed literature survey. Next up is the simulation and experimental setup. The simulations helped in determining a correct experimental setup. The results were compared as well. The final goal was to obtain an efficient electricity that can help the end consumer.

An overview of complete thesis is given in the next section as well.

1.5 Thesis Organization:

Chapter 1 gives a detailed introduction about the thesis, motivation behind the thesis, scope and overview of the thesis.

Chapter 2 is a detailed literature survey of the topic. Research gap is also found in this part. Problem statement is defined to.

Chapter 3 is the explanation of design of experiments including simulations and their results.

Chapter 4 is dedicated to the experimental setup of the setup. It describes the complete process of experimentation.

Chapter 5 is the concluding part. Results are shown and compared in this part. A conclusion is given regarding the thesis in this part along with some future scope of the work.

2 CHAPTER 2: "LITERATURE REVIEW"

Energy harvesting using domestic geyser is relatively new technique. There is a lot of research gap in this particular area. Novel geysers have been designed. Steam turbines are taken into considerations as well. A tiny part of literature revolves around the simulations as well.

Communication power towers is one of those areas where one needs continuous power. Any breakdown is costly. An eye-opening GEYSER approach has been described in the literature that enables green networked Data Centers to invigilate, optimize and recycle their energy consumption and production in becoming active participants in smart cities. Furthermore, the energy demand is increasing and as a result, they are not enough. These types of steps should be considered as a beginning. A conceptual architecture discussed with respect to Smart grids and smart cities has also designed[5].

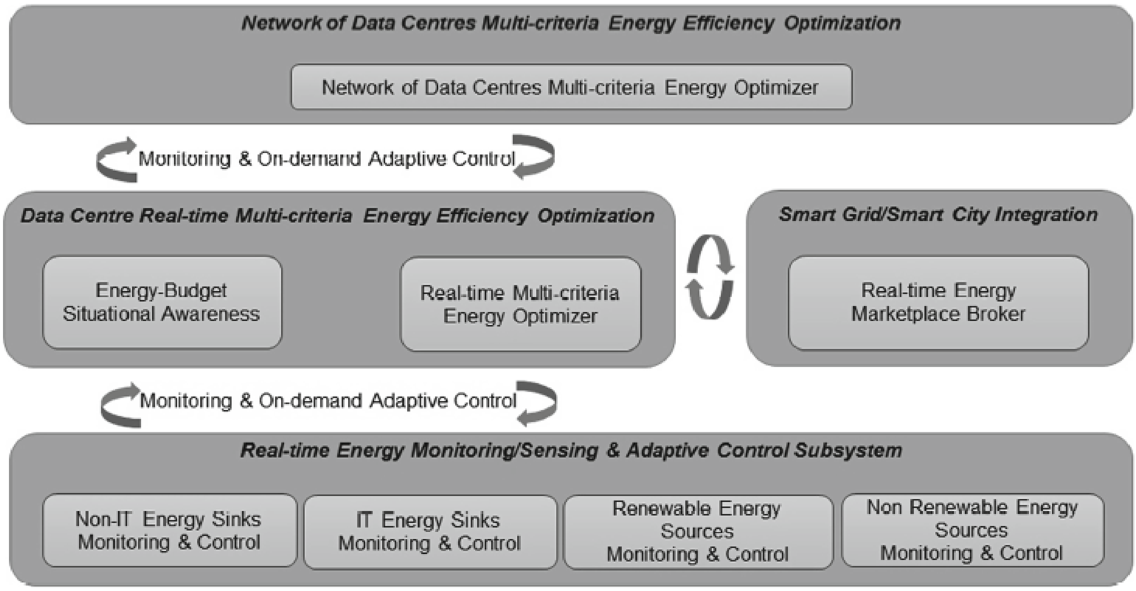

Figure 2: GEYSER conceptual architecture[5]

Piezoelectric material has been finding its importance now a days. It has many advantages in renewability and eco-friendly nature. A hybrid approach has also been used for energy harvesting. Piezo-electric material and wind energy has also been combined to harvest energy. Vortex-induced vibration energy harvesters were used with piezoelectric materials to enhance their energy output. Vortex Induced Vibration (VIV) energy harvesters work in an energy-saving mode when the frequency of vortex shedding becomes nearly equal to one of the natural frequencies of the dynamic structure. Therefore, with proper design, the VIV energy harvester can adapt well to low-speed wind currents and perform well in the low wind speed range. Lattice-Boltzmann is applied in the end to approximate the strength of vortex-induced vibrations and the pressure distribution[6].

Talking about wind energy, there are certain places in the world where wind energy is basically impractical. Highway wind turbines are the solution for those places. Vertical Axis Wind Turbines (VAWT) can be used in this regard. They can be placed at the brinks of roads so that energy could be produced by vehicles moving in both directions. Two things are measured. First is the wind speed of vehicles passing by and second is the wind power from VAWT at a series of anemometer heights on the sides of the road. As depicted by the results, 48 watts of power is generated by the vehicles which basically becomes an average of 4.4m/s. The measured data shows an efficiency of 34.6 percent which is depicted on the power curve. This is quite amazing for future prospects[7].

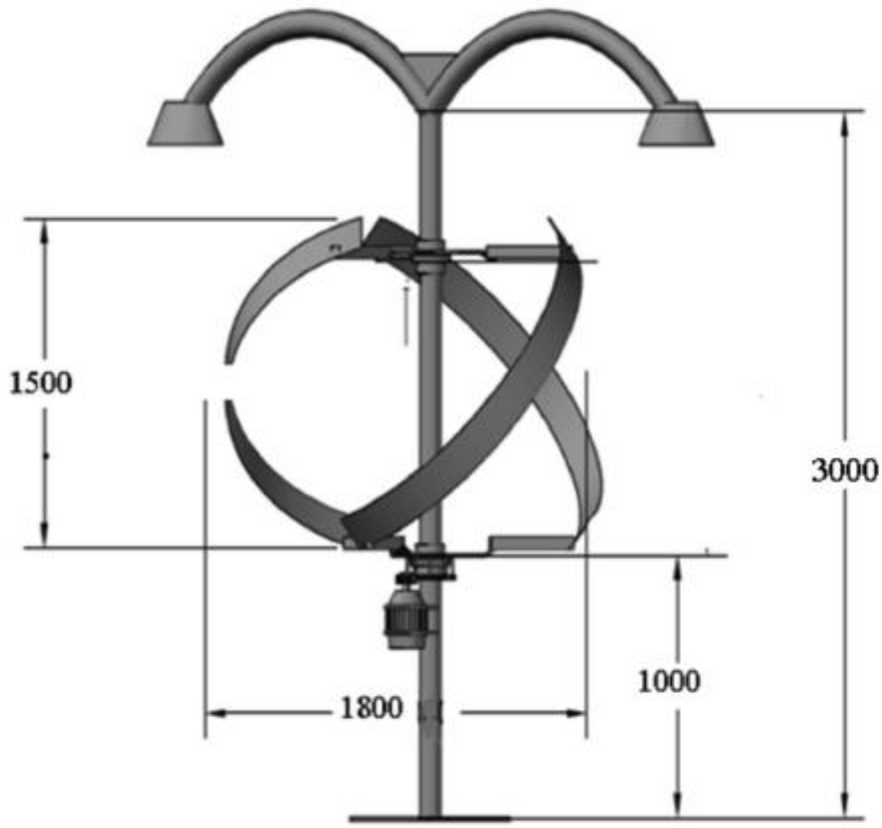

Figure 3: VAWT design[7]

The results from this experiment were very admirable. Such that this idea could be used to further expand the energy-generation network and can provide cheap energy through this process. The results from this research are shown below:

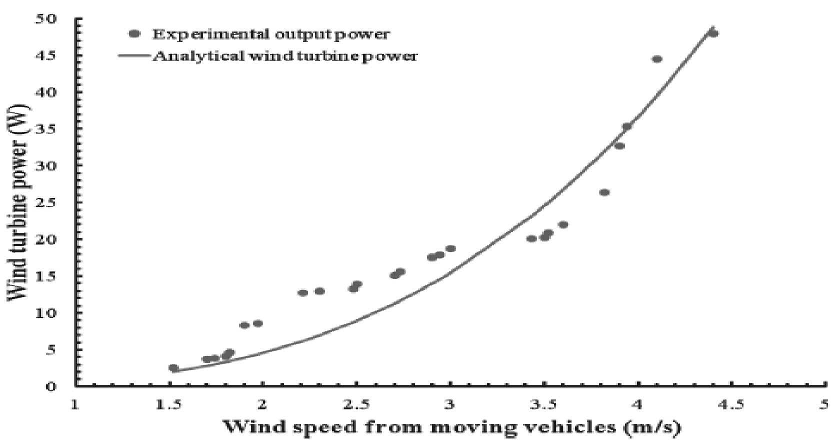

Figure 4: Experimental output results from VAWT design[7]

Talking about wind energy, one should not forget about solar energy. Hybrid devices, that can extract or scavenge solar energy and can store this energy electrochemically are getting popular day by day. Smart devices or IoT based devices have been developed in this perspective. The major aim was to minimize the energy breakdown interruptions. Several different integration methods can be used to extract solar energy directly and store the harvested energy in a hybrid device. One way to group these multiple devices is to systemize the device framework based on the number of electrodes[8].

Researchers have studied about different techniques as mentioned above. The major advantage of such devices is that energy loss is less than as compared to an extra capacitance layer which is added to store the energy. This would drastically increase the chances to use the energy with much efficiency as compared to other devices.

Moving on, kinetic energy extraction has built its repute in the last decade. Two things still stand in its path. One is low-frequency and the other is the broadband operation. This is the reason why this technology is still hard to implement in low powered IoT devices. Piezoelectric transduction has been used to convert rotational kinetic energy into electricity. In order to expand the operating range, non-linear behavior, which is often considered undesirable and problematic in practical applications, was deliberately introduced into power harvesters and has been extensively studied over the past decade[9].

Bi-stable rotational harvesters have been developed to tackle this situation. Simulink models and their analysis have been done along with the results (Figure 5) in order to create a physical and experimental model that could help in energy harvesting[9].

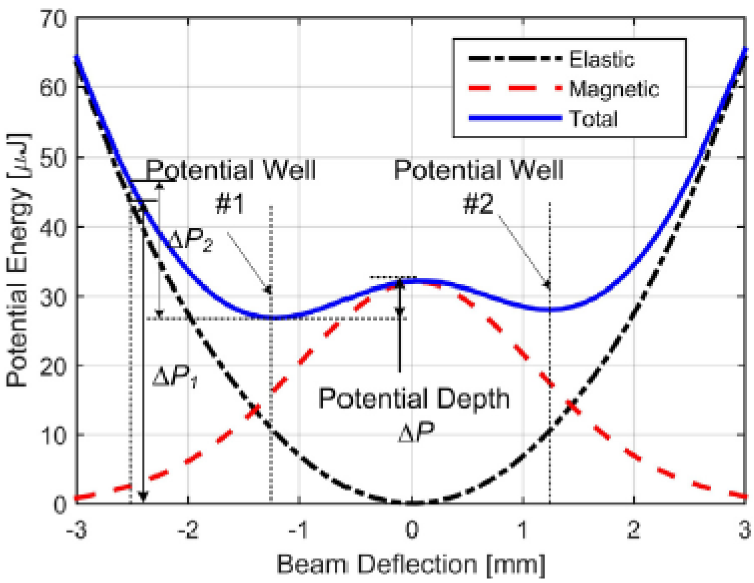

Figure 5: Potential Energy of Bi-stable rotational harvester[9]

The results showed two things. There are two modes in which the harvester operates. In the double-well mode, the end result is higher due to its high-energy orbit. In the single-well mode, the displacement and the output are restricted. As a result, a considerable relationship between input force and height of potential barrier should be developed in order to facilitate the experimental set-up and achieve harvesting which is effective and useable. The asymmetric configuration can be observed with a positive or negative initiation and termination[9].

One of the major parts in these kinds of set-ups is the battery where the energy is stored eventually. Researchers have tried to understand the different types of available batteries and how they are not enough for energy storage and how much losses they produce.

Integrated Power packs which include solar cells, lithium-ion batteries, piezoelectric materials, fuel cells, etc., have been the talk of the hour. Multiple types of integrated packs have been developed and are under study on how they can be made more efficient[10].

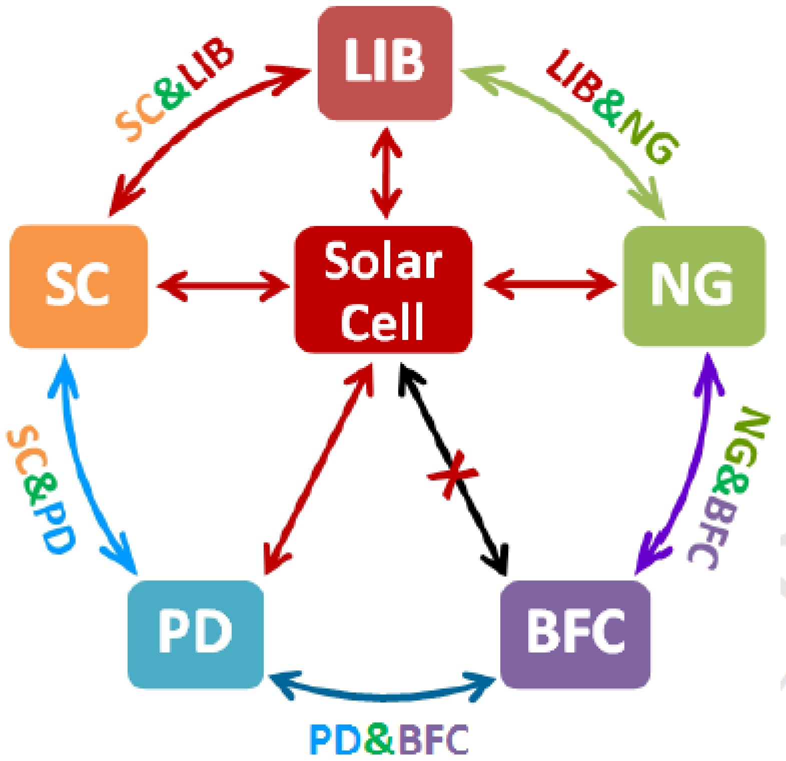

Figure 6: Integrated Power Packs[10]

Nanogenerators have been developed in order to harvest small amount of energy and convert them into electricity. PENG and TENG are the primary members of Nanogenerators. It has been found that portable electronic devices and devices with Internet of Things would their main application. Lithium-ion batteries and Supercapacitors have gained importance as well to store electrical charges. Moreover, biofuel cells have also gained importance in this regard. They are considered as a new type of energy conversion technology because they can operate in mild conditions. Another important factor is that they not only produce electric energy but also help in consuming a lot of organic waste[10].

The integration of these technologies can be of great benefit. For instance, lithium-ion batteries and supercapacitors have been combined and the results were pretty good. Their charge/discharge capacities could be increased due to their anode and cathode combinations. This would help in overcoming problems regards low-density, high-power etc. while storing and using the electrical charge.

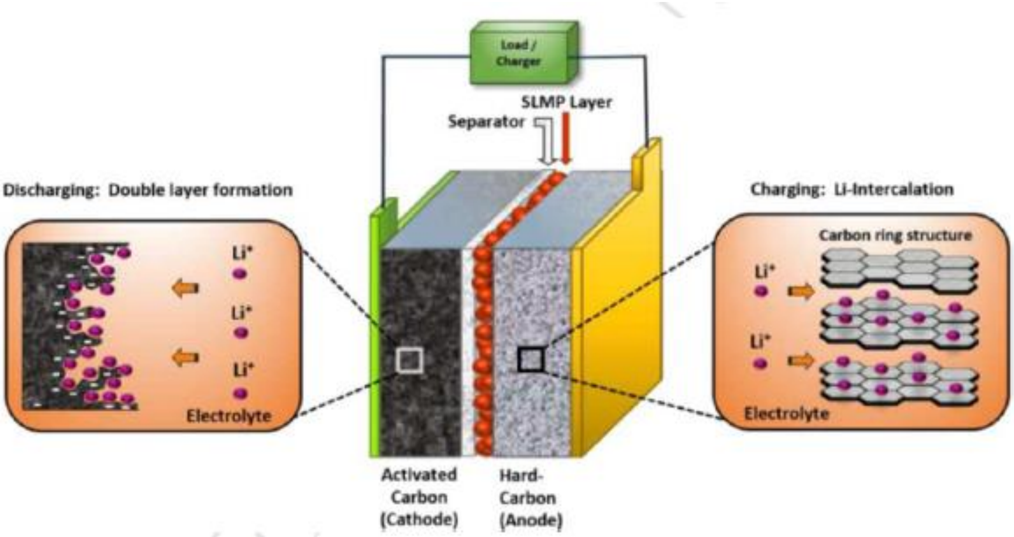

Figure 7: Charge and Discharge process[10]

In the same fashion, lithium-ion batteries and nanogenerators could be combined as well. Nanogenerators could also be combined with the biofuel cells that would help in increasing the efficiency of producing, storing and utilizing the electrical energy[10].

Wireless sensor Networks are widely used in many applications. Military applications are one of them. But their operational lifetime is less. In order to increase the operational lifetime of WSN, a hybrid device is proposed. As depicted through their block architecture (Figure 7), they can be deployed in different energy forms including solar, wind, electromagnetic and vibration energy[11].

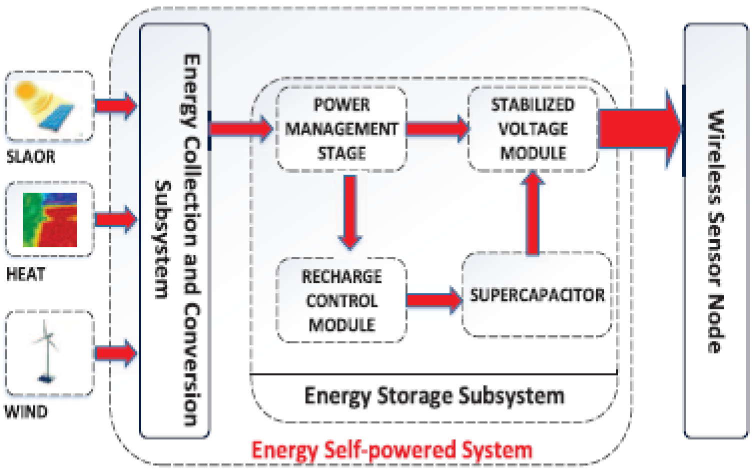

Figure 8: Block architecture of self-powered WSN node system[11]

The controller and circuit part are not relevant to our thesis. This article has provided us the knowledge about different integrated circuits and inductors so that we can choose readymade circuits in order to harvest energy and store it in the battery properly. Multi-Energy Harvester Subsystem and energy storage subsystems have been developed in this research which have provided an insight on how these systems work. This includes Wind Harvester Subsystem, Solar harvester subsystem, Heat Harvester subsystem and energy storage subsystem[11].

The design section in the energy harvesting systems is the most important part in this whole thesis.

We have previously discussed how wind energy is important and how it can be effective in energy harvesting. The problem is that how can it be efficient where wind doesn't blow enough. Devices have been developed in order to overcome this problem. Triboelectric-electromagnetic hybrid nanogenerator has been developed in this regard[12].

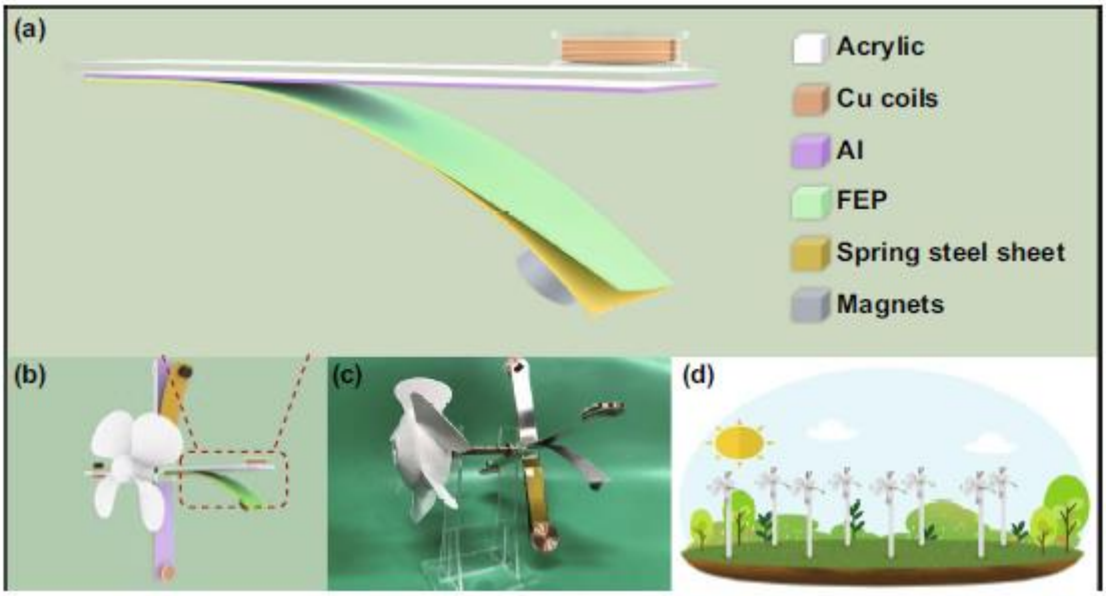

Figure 9: Different schematics of W-HNG[12]

It was tested mechanically and electrically as well. Their performances were measured separately in order to check that whether these two fit with each other or not. It shows that the output voltage increases as the resistance increases for both TENG and EMG, and due to the ohm loss, the short circuit current follows a reverse trend[12].

Hybrid Energy harvesting systems are the future. Vibration induced is one part of it. In this regard research has been done where different energy harvesting concepts are provided. One such paper provides two kinds of energy harvesting concepts, where the piezoelectric patch is assembled with the immovable end of the cantilever beam and the electromagnetic device is attached to the free end of the cantilever beam. The device is one-ended and attached to the floor. The results induced by the vibration of this solid surface on energy harvesting are neglected. The electromagnetic devices that provide energy harvesting and vibrate the beam element are structurally identical in the stated hybrid system. Both devices are placed in the same place on the facing beam. Out of the two devices, one is attached to the ground and the other is attached to the main beam with a secondary parallel beam element. Thus, the electromagnetic device that collects energy or vibrates the beam element can be changed so that it can be on the sub - or be top of the main support member[13].

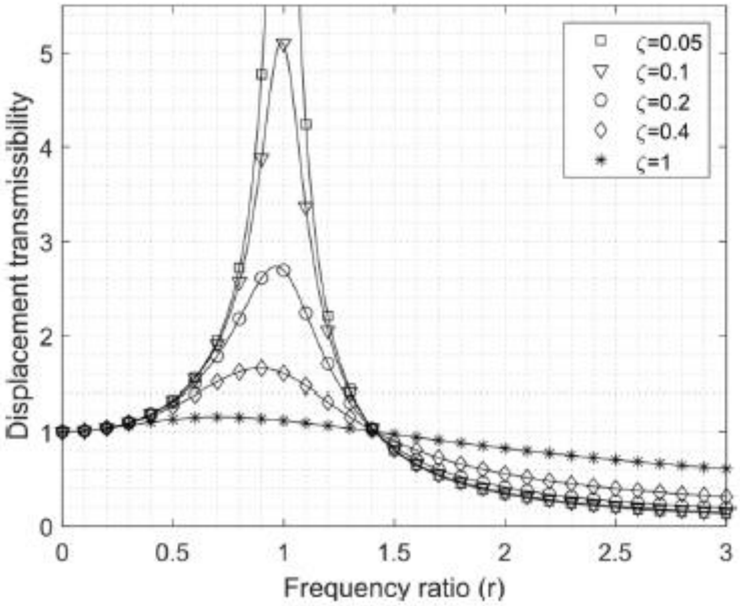

Figure 10: Variation of Displacement[13]

Sustainable green harvesting energy harvesting have gained a lot of importance in the recent times for their potential use in self-powered smart wireless sensor network. Their main problem, as already discussed, is that they are not long lasting. That is why Different systems have been developed and are integrated with WSN networks. The systems are classified into different categories based on their structure. Mechanical Energy harvesting systems include Electromagnetic Induction-based generator, Piezoelectric effect-based generator and Triboelectric Effect-based generator. Then comes Thermal energy Harvesting systems that include Thermoelectric Effect-based generator and Pyroelectric Effect-based generator. Lat but not the least are Solar Energy harvesting systems[14].

These systems are integrated with one another in order to make Hybrid Energy Harvesting system. Any of the above-mentioned technologies could be combined and used for energy harvesting.

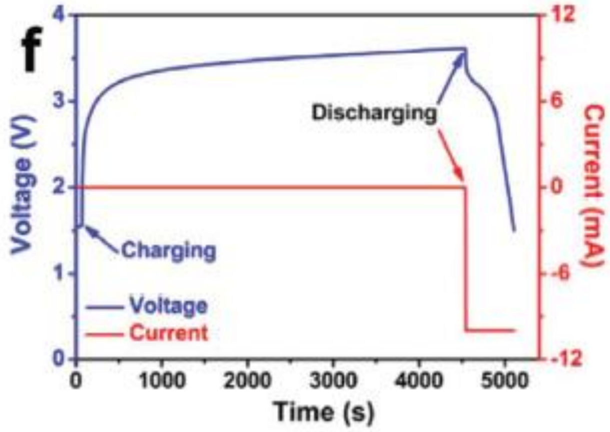

Figure 11: Energy charging and discharging curve by hybrid nanogenerator[14]

In 1913 [15], Nikola Tesla has proposed a new design for the turbines. It is basically a bladeless turbine which generate energy using centripetal force. In some literature, Tesla turbine has also been mentioned as bladeless turbine. The reason behind this idea is, Tesla wanted to develop a light weighted engine whose ultimate goal is to fly. In short, he wanted to develop a fling machine ending in developing a Tesla turbine. The researchers and scientist in the field of turbines, and similar field also used the words like multiple disk turbines, boundary layer turbomachinery, or shear force turbines. As it has contained all these features. There are certain advantages and certain disadvantages of Tesla turbines over conventional turbines. The advantages of Tesla turbines are enlisted as follows.

1. The design for the Tesla turbines is quite easy and efficient as compared to the conventional turbines.
2. Tesla turbines have used disks as a replacement for blades. So, these bladeless turbines cut the manufacturing cost of disks as well and can easily be manufactured as compared to other turbines. [16]
3. The conventional turbines are useful for a single type of fluid but due to the bladeless nature of Tesla turbines, they have the property to work with any type of fluid without damaging the internal machinery. [17]
4. These turbines are highly efficient as compared to the other turbines; one can easily rotate them in both directions by having pre-installed modules at the back end of this machinery.
5. The main ingredients of Tesla turbines are aluminium and acrylic. During the analysis of the Tesla turbine i.e., performance analysis of such system it has observed that the head loss of the total system is 0.44m which is very low as compared to other conventional turbines available or used worldwide. [18]
6. The torque for these turbines is also a very important factor in this regard. The torque of these machines is also quite high on the basis of which they can lift more and more fluid with greater mass flow rate. The torque measured for Tesla turbines are found to be 0.021 Nm.
7. Tesla turbines can also be used in small applications like one can install such devices under water sink. While washing dishes, with the help of water mass flow, the Tesla turbine can generate electricity. This feature attracts the homeowner because one can generate energy every time they wash dishes, do laundry, flushing the toilet etc.

Apart from all of the advantages mentioned above there are different disadvantages of such turbines as well. By having the comparison of advantages and disadvantages of these, the reader can understand the quality of these machinery better. The disadvantages [19] of the Tesla turbines are as follows.

- These are not useful when high power work is required.

- The efficiency of the Tesla turbines depends on the inflow and outflow of the mass.
- Smaller flow rate is required in the case of tesla turbines when one wants higher efficiency.

So, by finding and comparing all the advantages and disadvantages of Tesla turbine one can chose between them or the conventional turbines depending on the nature of the application required by the user. This will give a new researcher in this field a better view as all the properties is enlisted in a single document.

3 CHAPTER 3: "DESIGN OF EXPERIMENTS"

3.1 Selection of Turbine parameters:

As explained already, the turbine is the most important part of this project. It resembles to the tesla turbine. Its parameters were decided after reading the literature. The table below shows the complete characteristics of the turbine:

Design Parameter	**Value**
Inlet pipe	0.5 inch
Outlet pipe	0.1-inch exit
Number of discs	4
Size of discs	6-inch diameter
Shaft length	1 inch
Depth of groove	2 inches
Outer diameter of shaft	1.5 inch
Casing (Outer diameter)	6.75 inch
RPM	1300

Table 2: Design parameters

3.1.1 Material of Turbine:

ASME 836 material characteristics are present. Mild steel it can be called. It is a composition of Carbon, manganese, phosphorous, Silicon, sulfur and titanium. Due to its greater tensile (55ksi) and yield strength (25ksi), it becomes the perfect material from which the turbine should be made. These properties are certified on the basis of test material which endures heat treatments to ensure glass-coating operations.

3.1.2 Physics behind the turbine:

The exhaust and outlet of turbine is given close to the radius because when the steam is cooled down, the kinetic is lowered and as result, the cool steam is removed from the apparatus.

At the outer points of the discs, the steam is contained and motions through the system. Eventually after cooling down, it moves out of the assembly.

This whole process revolves around priming. It is a process of removing air from the pumps and suction lines to permit atmospheric pressure and flooding pressure to cause liquid to flow into the pump. It is so much important that without priming, the pumps would cease to function.

3.2 Selection of parameters:

This thesis is incomplete without the selection of appropriate parameters which include temperature, pressure and Mass flow rate. Material for the whole system was selected after studying the properties and appropriate literature. The next step is to select the appropriate parameters on which the whole system will work. The parameters will be explained in the next chapter. However, a brief introduction is given here.

Since it is a simulation-based model and thesis, we need to understand that the results might differ while working and building an actual one. But this model will help in building one that is efficient and that will help people in producing alternative energy. The parameters that were taken into account are given below:

a) Minimum Static Pressure
b) Minimum Total Pressure
c) Minimum Dynamic Pressure
d) Minimum Temperature
e) Mass (Fluid)
f) Mass Flow Rate
g) Minimum Velocity
h) Minimum Shear Stress
i) Torque (Z)
j) Minimum Temperature (Solid)
k) Minimum Mass Fraction of Steam

3.3 Design of Experiments:

Experiments are performed in two conditions:

i. Full-load condition
ii. No-load condition

A total of 378 iterations were performed in full-load conditions and 121 iterations in the no-load conditions. The parameters defined above have been measured during the both conditions; the detail of which we will see in the next chapter. A small mathematical model was also designed that helped in performing the experiments. The equations related to the mathematical model are given below:

P = Flow rate x g x h x efficiency **(A)**

We know that

P = W/t **(B)**

And

W = F x d

F = m x g

Putting the above equations in **(A)**, we get

P = m x g x d **(C)**

It can also be written as

P = (m x g x h) / t **(D)**

Since flow rate = m/time, equation **(D)** becomes,

P = flow rate x g x h x efficiency **(E)**

The flow rate of the system is 80 liter/sec. Similarly, h is 18m. Using these values, the above equation becomes,

P = 80 x 18 x 9.8 x 0.65

P = 9.17kW

Since we have the value of P, we can also calculate the value of speed which is given below:

Speed = $(\sqrt{h} * 38) / dt$

Speed = $(\sqrt{18} * 38) / 0.3$

Speed = 537 RPM

We can also calculate the runaway speed which is given below:

Runaway Speed = Speed at full load * 1.8

Runaway Speed = 537 * 1.8

Runaway Speed = 967 RPM

4 CHAPTER 4: “METHODOLOGY”

In this chapter, a detailed summary of the project description has been explained. The Assembly of the project has been discussed, and their related results and calculations have been shown. A detailed summarization of this project and detail of each and every portion will be discussed in the later subsections of this chapter. A brief introduction to assembly will be explained in order to start this chapter.

4.1 Description of Assembly

Assembly is the most important part of product designing. While working with assembling or explaining it one must know about all the parts and components associated with it. One must know the smaller details of each and every component that has been used to assemble the given prototype. This can be helpful for a layman to understand the project description. This assembly description also acts as evidence of the work that has been done in order to complete the thesis. An explained description of assembly helps the researcher to simulate and obtain results from the simulation software. In order to start all the parts of this assembly have been listed as follows.

1. Geyser
2. Generator
3. Blower

4.1.1 Geyser

In this subsection, a detailed discussion will be done on the geyser and why geyser is required for this project. Geyser plays an important role in this prototype as with the help of this we can generate thermal energy which can be used in the later components for working. The geyser used here in this prototype has the following specifications.

1. It has a vessel in which it holds water. This vessel is made up of stainless steel.
2. Glass wool is used here which acts as an insulator between the inner body and the outer casing so that there is no transfer of temperature towards the outside body.
3. The insulation which is made up of glass wool has a thickness of about 3-6 inches, which is enough in order to stop the effect of heating toward the outer body of the geyser.
4. This geyser has also a built-in thermocouple made up of PT-100 with the help of which it can maintain and control the inside temperature of the fluid on its own. The temperature can be set by the user himself from the outside as well.
5. There is an open exhaust in the geyser for hot air exhaust and fresh air intake in order to maintain the temperature of the system.
6. The mechanism for heating that has been used inside the geyser is basically made up of copper tubes. The reason for choosing this copper tube-based geyser as copper is the best conductor of heat and very minimal heat loss has been occurred while working with these as consumption of energy is another factor as well.
7. Finally, there is a main hole in geyser for cleaning and removing scale from the geyser as well.

The model of the geyser has been developed in solid works as well which will give a proper view inside the geyser and what are the mechanisms involved.

4.1.1.1 Geyser outside Full assembly

In this subsection, a complete general description of assembly has been explained. The general description of the outside assembly and its components has been discussed in the earlier section. A complete model of the geysers outside assembly is shown in the following figure.

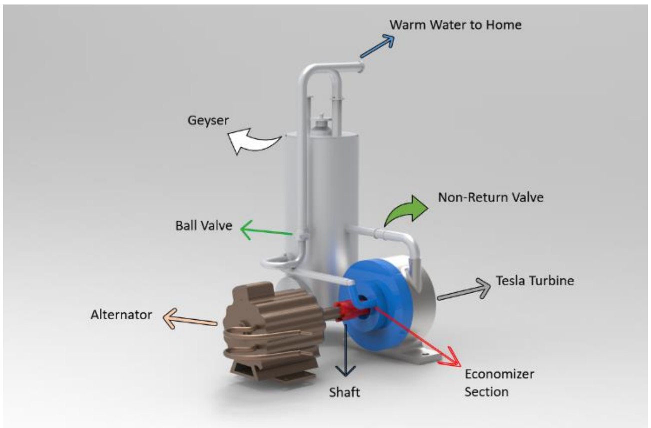

Figure 12: Geyser's Outer Assembly

4.1.1.2 Exhaust Valve

An exhaust valve has been added to this geyser in order to exhaust the hot air and intake the cold air as discussed earlier in previous sections. The valve is adjustable so that air outlet and inlet can be adjusted according to temperature specification. There are also programmable adjustable valves are also available which can adjust temperature on their own based in a feedback system.

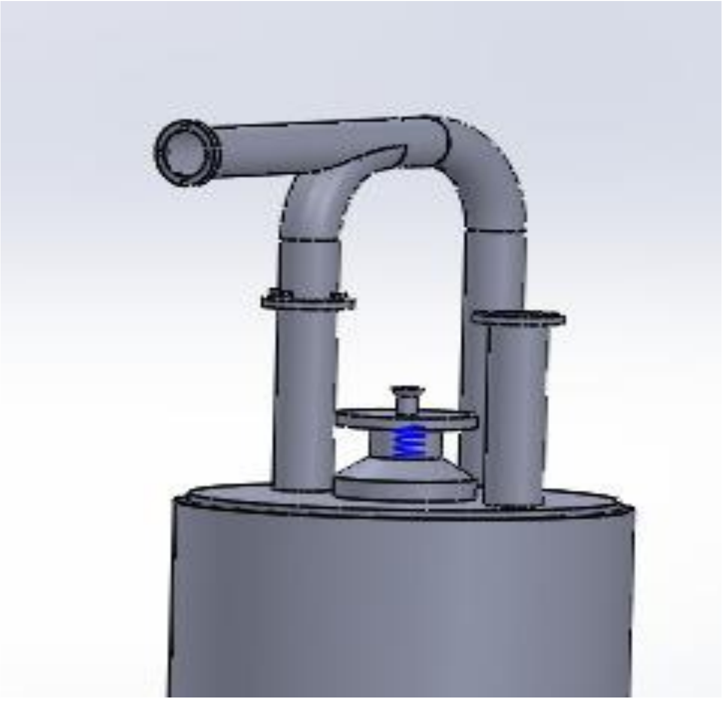

Figure 13: Geyser's Outside Valve

4.1.1.3 *Copper Tubes for Conducting Heat*

As discussed, earlier copper tubes are available inside the geyser for heat conduction in order to heat up the vessel so that the temperature of the water can be rise. Copper tube-based geyser have been selected for this project as copper are the best conductor of heat and can easily achieve higher temperatures. These copper tubes are very smaller in diameters and having larger lengths so that the conduction can becomes easy and more temperature can be achieved by using minimal energy consumption as energy consumption is also a main factor in this thesis. A figure showing inside of geyser having copper tubes is given as follows.

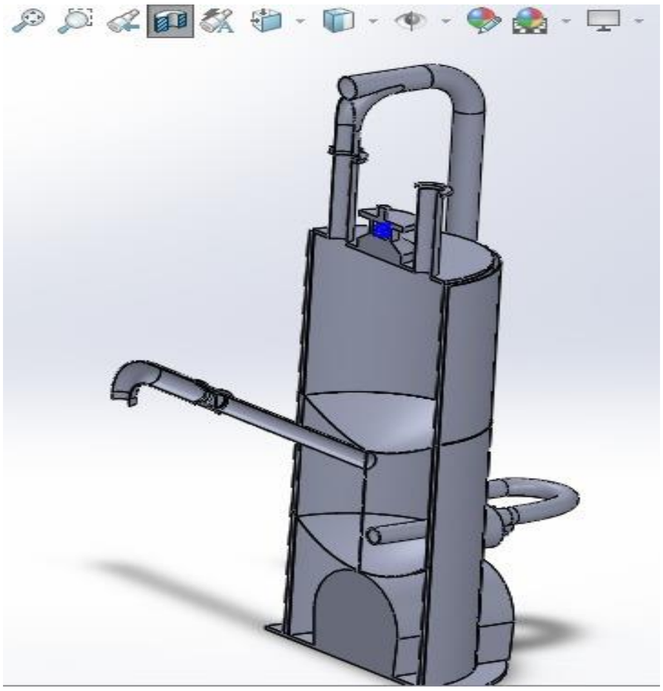

Figure 14: Inside View of Geyser having Copper Tubes Attached

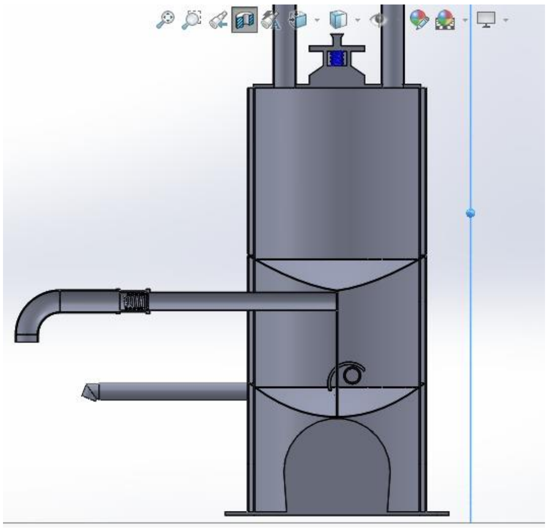

Figure 15: Cross Sectional View of Inside of Geyser

In the second figure shown above, there is a cross-sectional view of the inside of the geyser which shows the inlet and outlet of water that has been flown inside it. There is an inlet shown at the bottom left and an outlet shown on the top right. With the help of this mechanism, the heat has been transferred and the temperature has been adjusted.

4.1.2 Blower

The blower has been used here in order to evacuate the gases out from the chamber of the geyser. With the help of blower, the gases have been eliminated from the system and the fresh intake has been made possible. As the gas that has been produced as a result is basically methane gas which is combustible and a high rate of evacuation is required in order to remove the hazardous chemical. In order to select a blower for this project, the blower must have some features, these properties are as follows.

- The maximum throwing capacity should have been 3+ kg/minute as the gas is combustible and can provide damage to the system.
- The inlet and outlet of the blower must have been of same size.
- As steam is required here to produce. That is why the steam must have been produce quickly. So, if the water temperature is higher more steam can be produced and hence more energy can be obtained as a result.
- The blower should have been in such a form that it can bear a lot of pressure.

By considering all the above scenario in the mind the blower which has been selected for this project is having different specifications like it has the capability of 3.25 Kg/minute throw of air or gases, also its inlet and outlet are of same sizes. The temperature of steam can be increased quickly as the mechanism of heating is very proficient. The pressure of the steam that have been obtained at the turbine inlet is 3-6 pascal developed by blower. The shaft of the blower has also different specifications. Like the rpm of the shaft is basically 3000 rpm with the help of this high-speed mechanism the blower can throw the air outside with greater speed. The winding of the blower is three phase and nature of the winding or in other words they have star-delta connection that have been used for high current bearing and high-speed shafts. There are also four bearings have been used here in order to provide stability to the system. The rotation can be easy by having bearings as there are four bearings being used. There are other specifications as well which will be explained in the later sections.

4.1.3 Generator

The generator has been attached to the geyser in order to generate the energy required for the heating or transfer of heat. With the help of this heat and increase in temperature, the output from the generator has been received and can be utilized in various applications. The specifications and features associated with the generator are as follows.

- The generator has an output voltage capability of 24V. The maximum voltage we can obtain from the generator is 70 volts.
- It can give a current of 10A with up to 25 A.
- As the output received from the geyser is in AC form so we have to convert it into DC by using a full-wave rectifier so that charging of devices can be done.

- The output voltage that has been obtained in the form of DC can be calculated using the following formula. In this formula V out is the output obtained after the rectifier and V in is basically the input provided to the rectifier means the output is directly generated from the geyser.

$$V_{out} = \sqrt{3}\, V_{in}$$

- Copper wires are being used in this generator for the transmission of energy from one point to other. These copper wires are dual-core wires.

4.2 Turbines and Results

Turbines that have been used here have also different parts and specifications. Following are the parts of the turbines.

- Shaft
- Rotor
- Stator
- Inlet Pipe
- Exhaust Port

4.2.1 Shaft

The shaft of the turbine has the ability to connect the generator of the turbine. With the help of this the turbine runs at the same speed as the generator and hence produces energy which can be later on used in different applications. In simpler terms, the sole purpose of shaft of a turbine is to convert fluid flow motion into continuous energy.

In order to obtain a complete overview of a turbine having different parts following is the figure which shows better cross-sectional view of turbine.

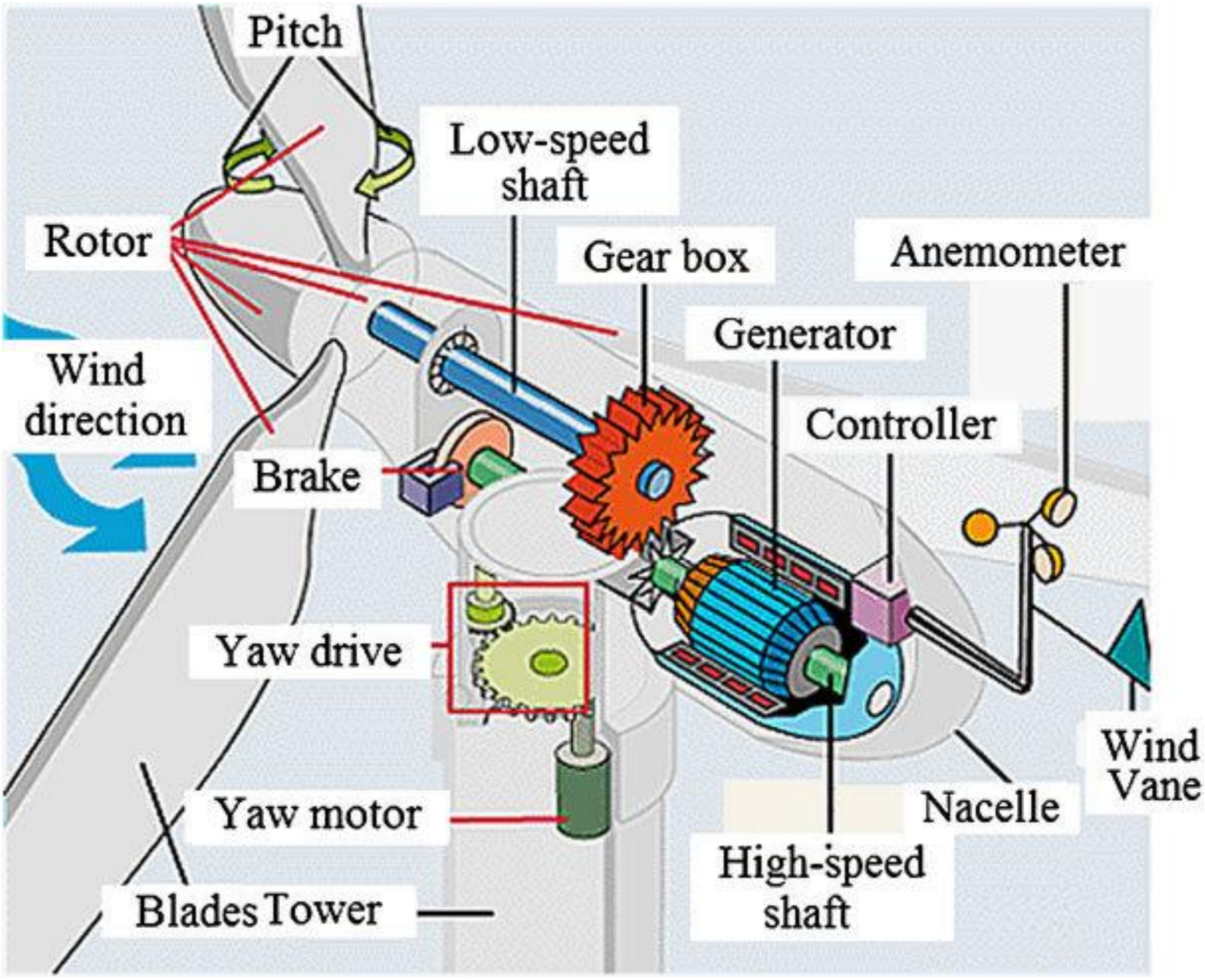

Figure 16: Inside view and different Parts of Turbine

4.2.1.1 Rotor

The rotor has different features associated with it. The rotor directly connected with the generator or in some cases may have connected with a series of gears or gear shafts. The series of gears are present in those cases where speed is an issue. The rotor played an important part in producing energy. The aerodynamic waves help the rotor to translate and at the back end the electricity has been generated.

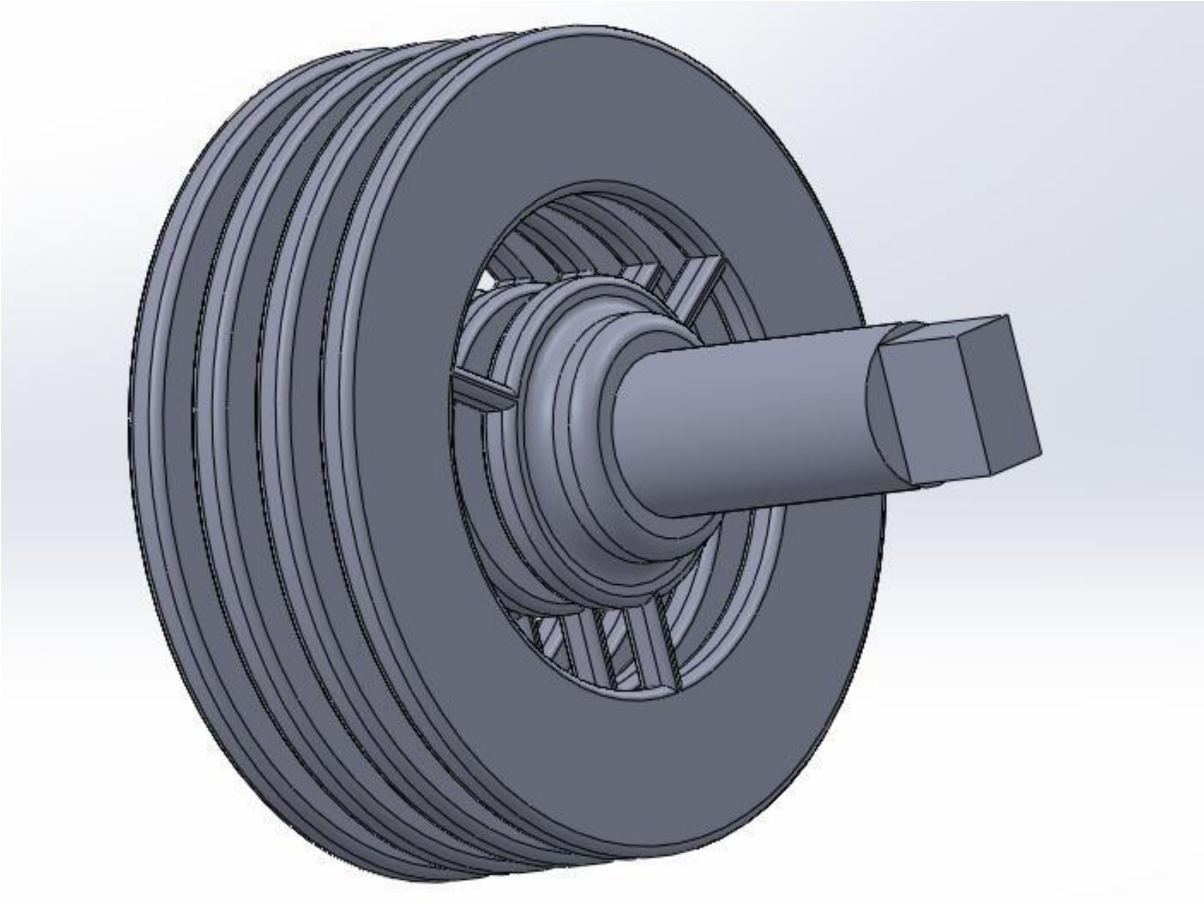

Figure 17: Turbine with rotor shaft

4.2.1.2 Stator

While designing a turbine, stator is also an important part as it contains blade with the help of which redirect flow of fluid can be done and hence with the help of these blades the rotor gets movement and as a result energy can be produced. These devices are also named in some cases as torque converter or steam turbines as well.

4.2.1.3 Inlet Pipe

An inlet pipe is an opening with the help of which the machine helps to intake the fluid or the air inside the mechanism. The practical demonstration in our daily life about the inlet pipe is the inlet of the compressor with the help of a rotor and stator the compressor intakes the fluid and with this intake energy the rotor circulates the fluid inside the compressor and eventually the fluid leaves the compressor from the outlet after gaining all the useful energy. Same is the case of inlet pipe in turbines but here the fluid is water and helps to suck water inside and the water obtain the energy which can be used in different aspects later on.

4.2.1.4 Exhaust Port

An exhaust hub or a port is available in turbines or steam engines with the help of which they can exhaust the extra energy and this extra energy can be evacuated in the air. This energy that has been exhausted from the system is the surplus amount of energy which has no use. The reason of evacuating this surplus air or energy as to maintain temperature and conditions which are required and to work within the given parameters.

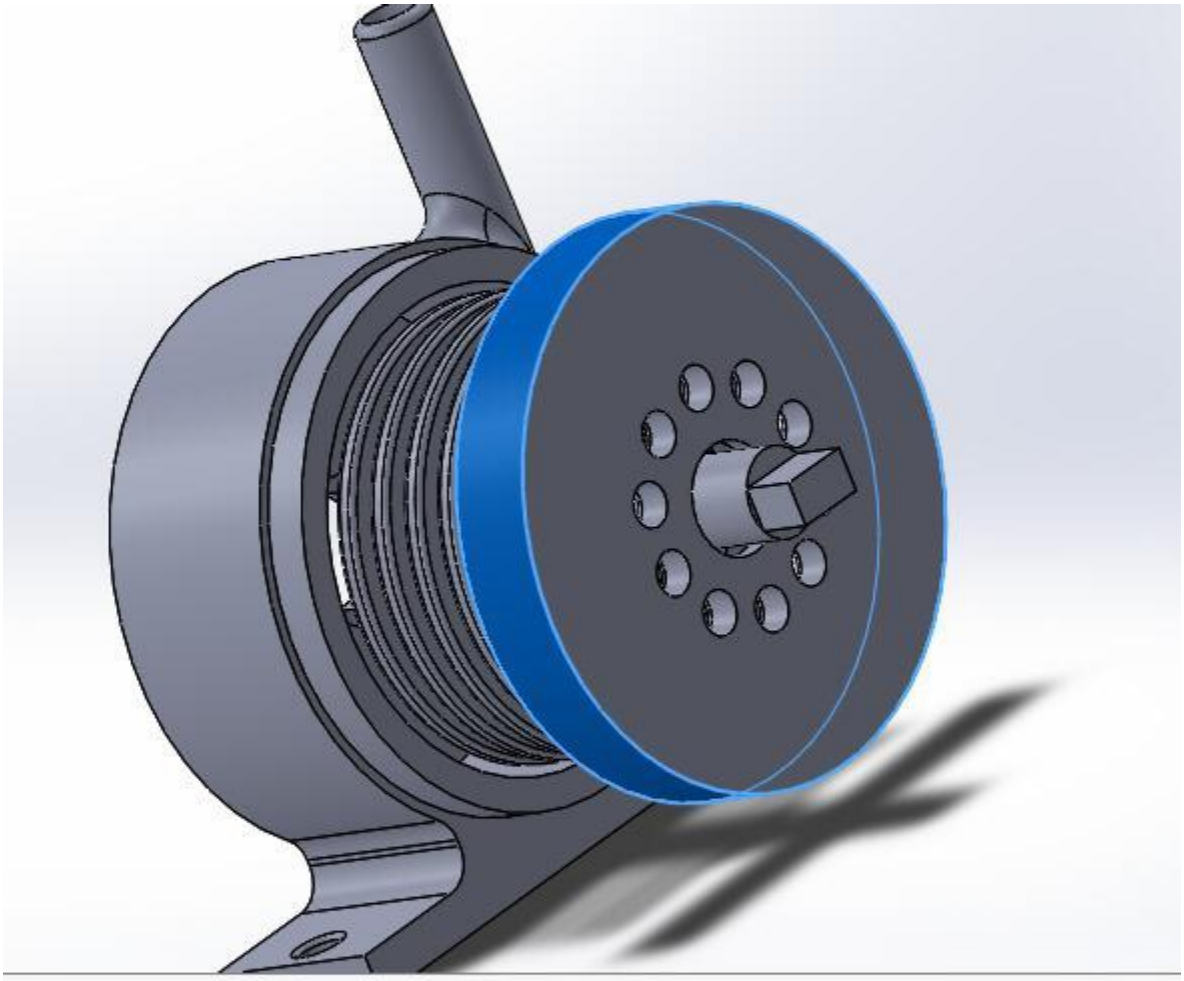

Figure 18: Complete turbine model

4.3 Behavior of Turbine at No Load Condition

In this subsection, the behavior of turbine at no load condition will be discussed with results and graphs. The parameters of turbines will be considered. This subsection will provide a guideway to the reader about how turbine will work under different conditions. For this purpose, a detailed graph has been shown and its description and explanation will be given on the basis of which future results will be inferred and this can prove the validity that our system works. These results are the simulation results obtained from SolidWorks where we have provided the assembly of the turbine as discussed in the earlier sections and we have also provided inputs and output parameters. The input parameters are usually the energy coming out of gases and the output parameter will be those results that we wanted to obtain from the turbine and the whole system. By having this graph and all the results that will be discussed here the system will be designed accordingly and on the basis of which future results will be obtained. In the following figure, there is a graph shown which shows us the behavior of turbine at no load condition. The explanation of this graph is explained in the later part of this subsection.

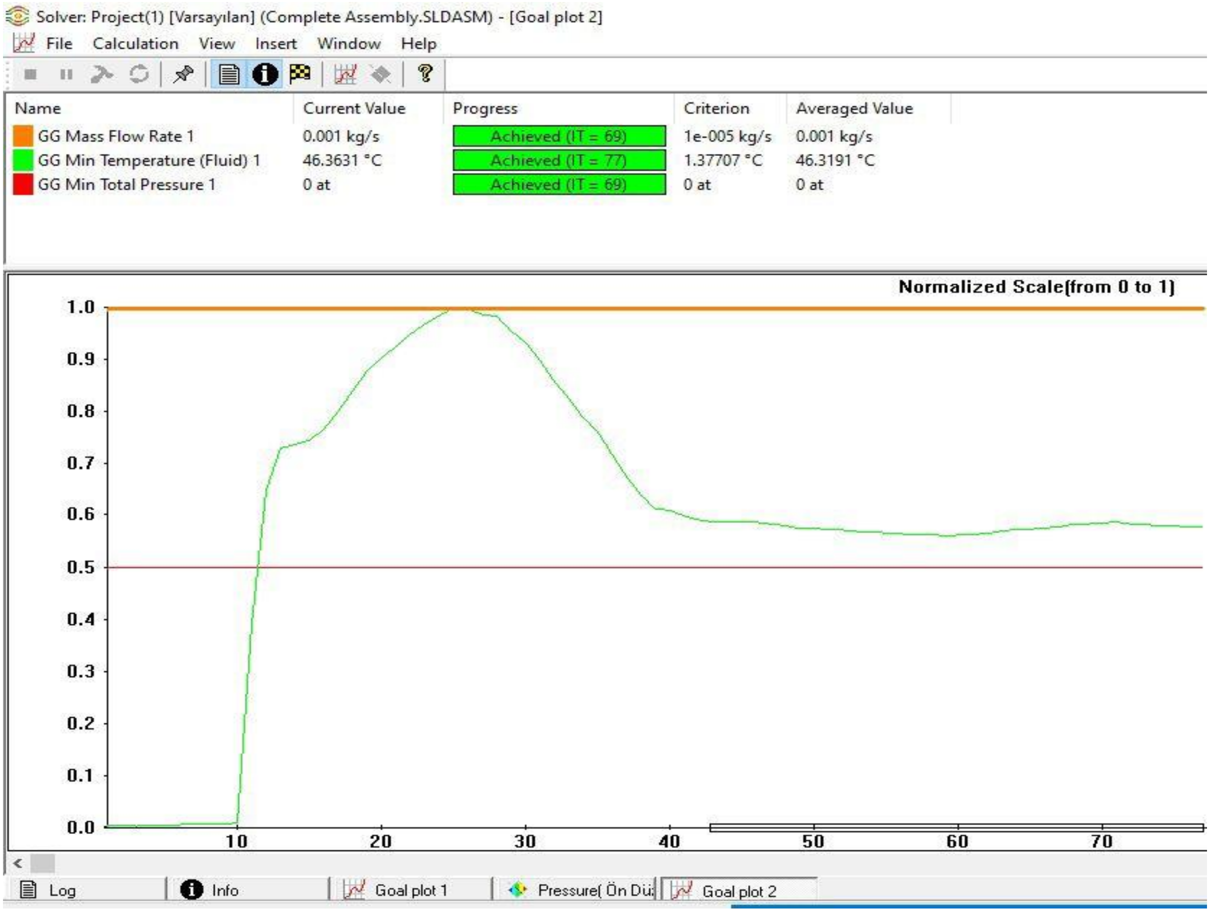

Figure 19: Behavior of Turbine at No Load Condition

From the figure shown above we have a graph between pressure and turbine's behavior. There are different input parameters that have been provided to the software in order to obtain the results. These parameters are as follows.

- Behavior of the turbine shown above is at no load condition which means there is no output attached with the turbine. The reason behind finding the behavior at no load condition verifies the quality of the turbine.
- The behavior of the turbine has also been judged with the internal pressure of the turbine at 0 atm as there is no output attached means there is no load so the internal pressure is 0 atm in this case.
- There are two factors involved in this case as shown in graph one is the pressure and other one is temperature which varies in order to obtain the results. Different number of iterations have been applied in order to obtain more accurate and precise results. The number of iterations for temperature are 74 and similarly the number of iterations for pressure are 66.

In the same way, by applying all the inputs enlisted above there are certain outputs which tells us the behavior of the turbine by looking at the graph. We can obtain different results by observing the above graph these are as follows.

- The flow rate at no load condition for the designed turbine is 0.01kg/s.

- The flow rate decreases as more load has been applied to the turbine and increases when there is lesser load.
- In the graph shown above the green line indicates temperature, orange line shows the flow rate, and red line shows the total pressure.

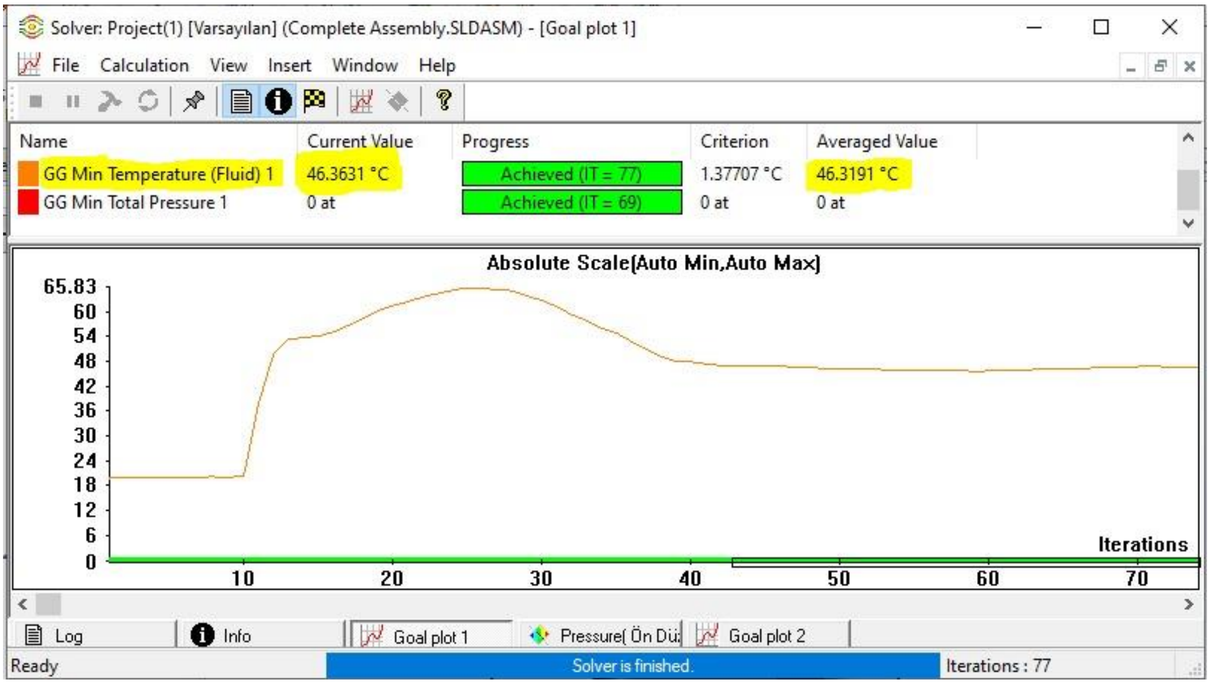

Figure 20: Variation of Temperature

- As observed from the graph the flow rate and the pressure in this case remains constant whereas temperature varies.
- The temperature gradually increases at lower pressure as shown, after reaching a certain point it starts decreasing and remains constant at the end part of the graph.
- There are different other parameters also shown in the above dialog box of the graph which shows the 0 atm pressure, 0.01kg/s flow rate, and minimum temperature of the fluid at 43.36 degrees.
- For better understanding of temperature there is another graph shown in the previous page which shows more clear behavior of the temperature and its exact values as indicated by the orange lines in the graph.
- The temperature remains constant initially and at sudden increases to 63 after reaching a certain point the temperature gradually decreases and remains constant at the end.

4.4 Flow Trajectory of Turbine

In the previous subsection a detailed discussion has been made on the temperature variation. In that figures or subsection there are only graphs which shows the temperature variation with respect to change in pressure. In this section, the variation of temperature has been observed at different trajectories. For this purpose, again simulation results are shown in the following figure. The figure shows us the behavior of fluid or in the case of turbine is steam by having different temperature variations. From the figure, we can observe that the temperature of the fluid which flow inside the turbine can reach up to 104.35 degrees with a lower can be achieved at 90 degrees. By observing the figure shown, we can find out the movement of the fluid inside the turbine having different temperature variation. By having these results, it can make understanding easy for the reader or the new researcher in this field that how these things work and what has actually happened inside a turbine. With the help of this rise in temperature we can generate energy which energy is supplied to the generator and after the generator the AC voltages are converting into DC volts by using bridge rectifier. After obtaining DC voltage from the bridge rectifier, we can obtain energy which can be utilized in charging purposes or running small appliances.

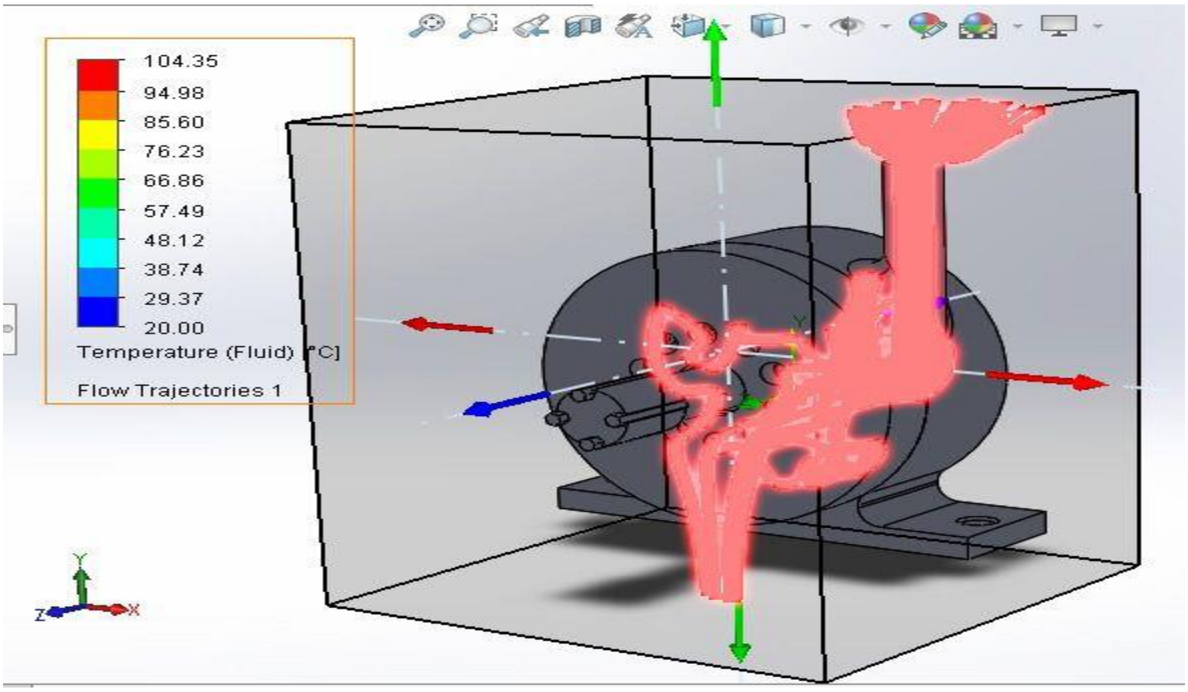

Figure 21: Simulation Result of Flow Trajectory of Turbine

5 CHAPTER 5: "RESULT AND DISCUSSION"

The previous section described about how the experiments were carried out. It also included the detailed description of assembly especially turbine. This section contains a detailed discussion on the simulation-based result obtained on SolidWorks. Different goals were met on two conditions; No-load and Full-load. We will analyze each on both conditions.

5.1 No-Load Vs. Full-Load

5.1.1 GG Minimum Mass Fraction of Steam 1:

This parameter was plotted against the number of iterations. Two graphs are shown below. First one is when there is no load is applied on the system. The second one is quite the opposite i.e., when the load is applied to the systems. The graphs depict the actual difference between the systems in both conditions.

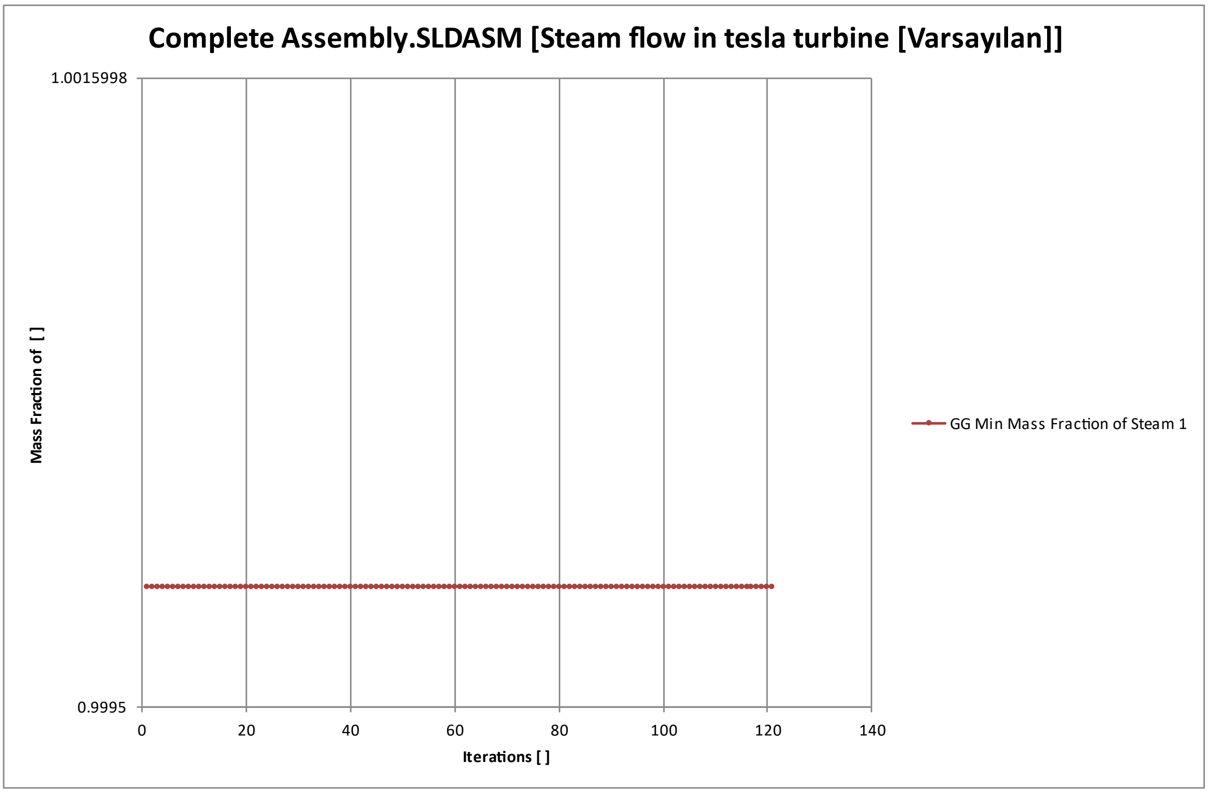

Figure 22: Min. Mass fraction of steam (No-load)

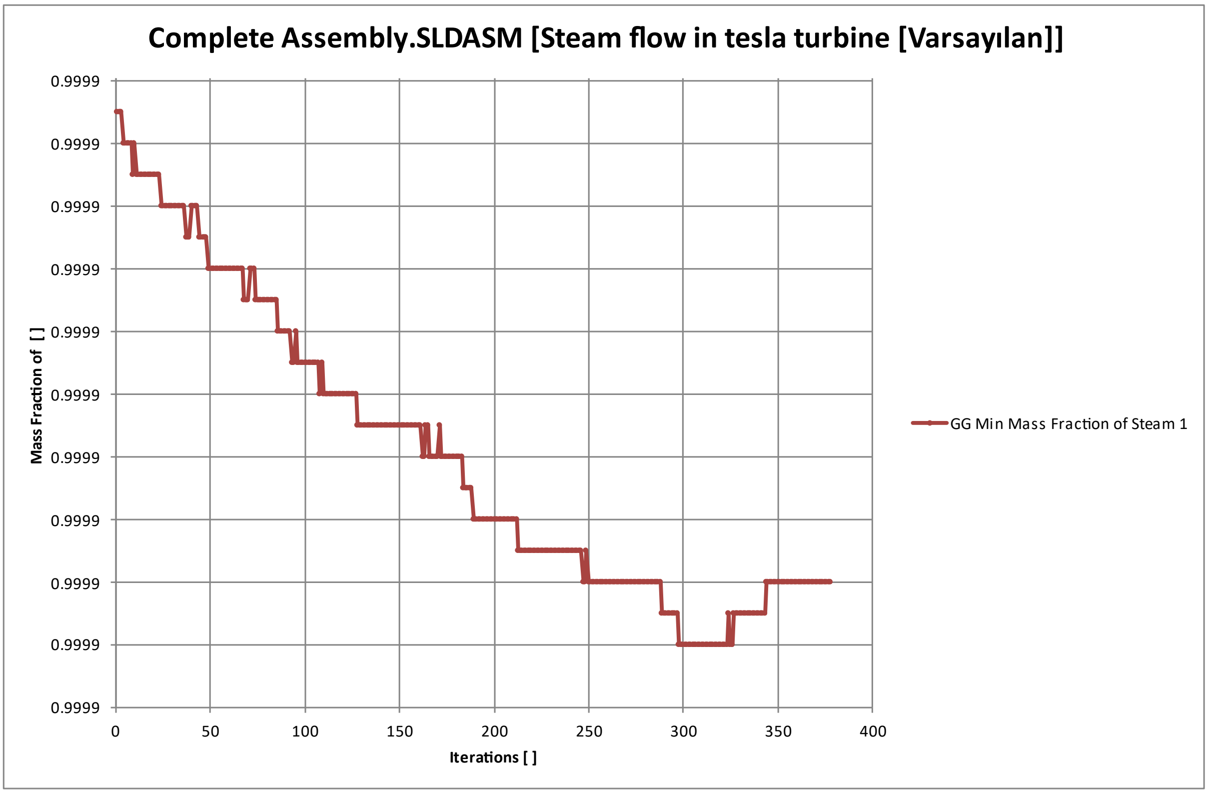

Figure 23: Min. Mass fraction of steam (Full-load)

5.1.2 GG Minimum Temperature (Solid) 1:

During experimentation, the minimum temperature had to be determined so that for any solid that is being used, the criterion could be found. This gain was performed for both no-load and full-load conditions. Both the graphs depict the difference. For no-load conditions, the temperature dropped to -60°C while in the full-load conditions it went down to -13,000°C. The difference parameter is load that was applied in different forms.

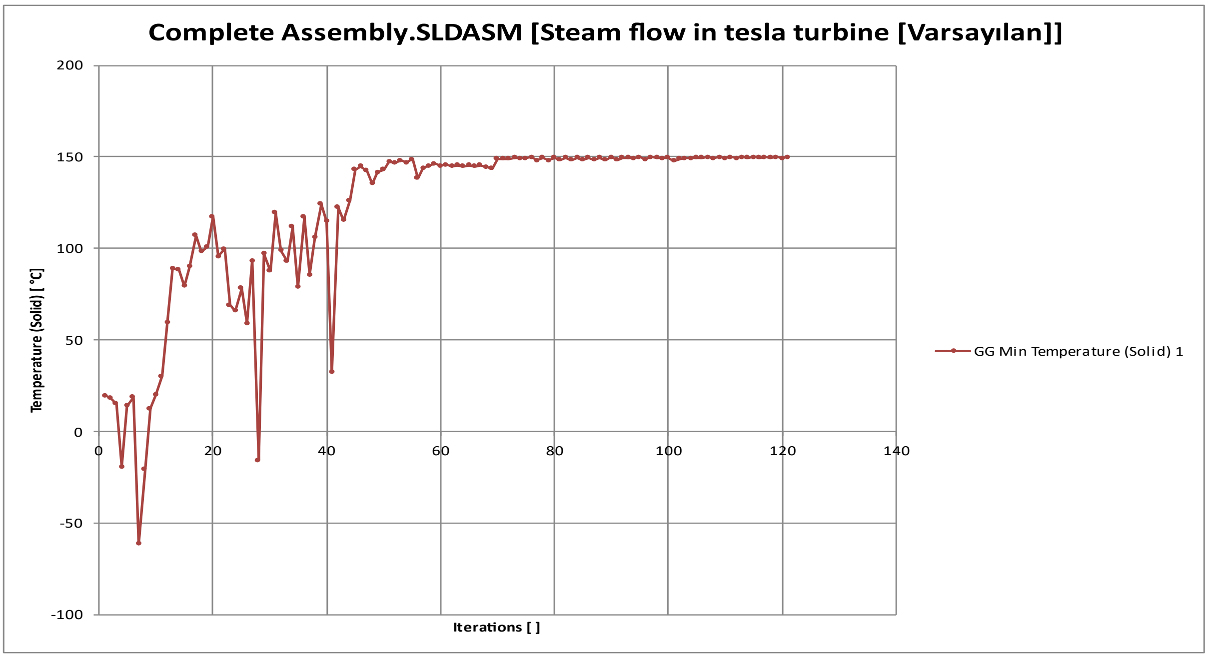

Figure 24: GG Minimum Temperature (Solid) 1 (No-load)

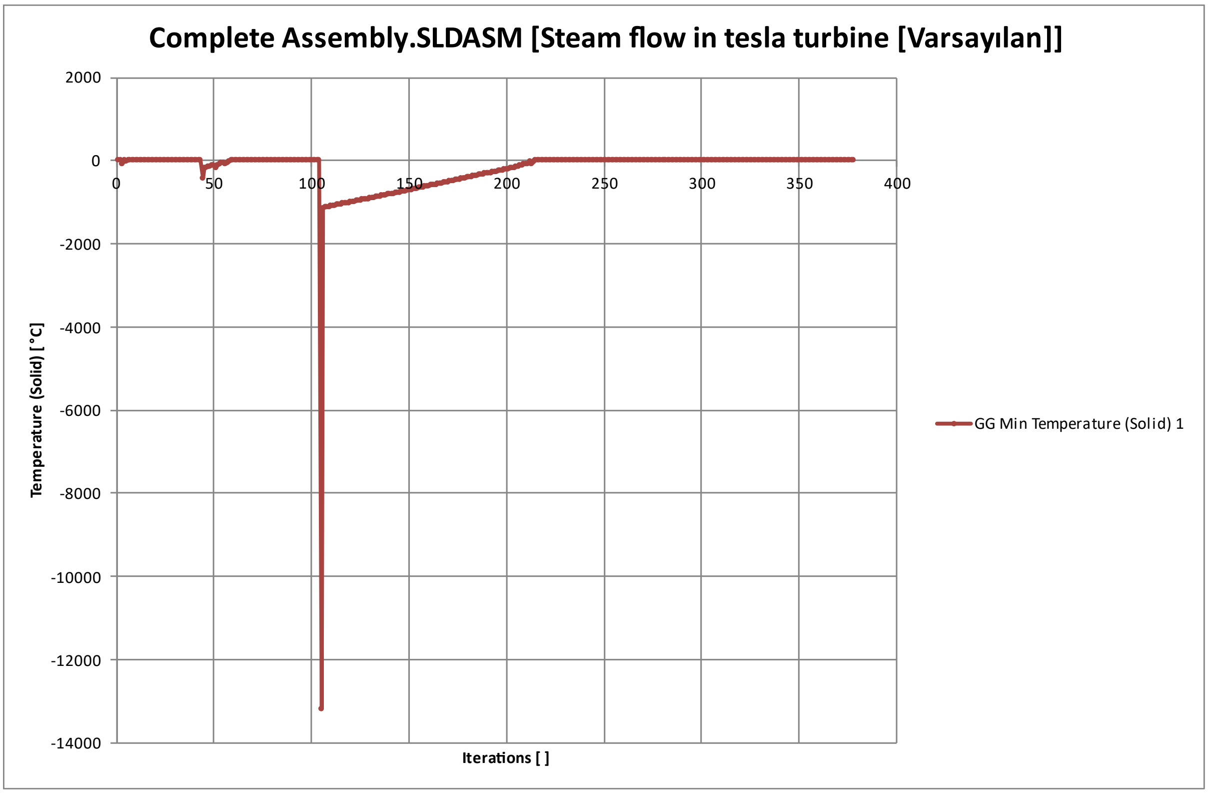

Figure 25: GG Minimum Temperature (Solid) 1 (Full-load)

5.1.3 GG Torque Z (1):

Any measure of force that causes an object to rotate around its axis is known as torque. As for the above-mentioned parameters, this too was simulated on both no-load and full-load conditions. Whenever the load is applied on the system, it draws more current and as result, the value of torque increases gradually. This tells us about how much torque is required during the system design whenever the system is tested on the extreme conditions.

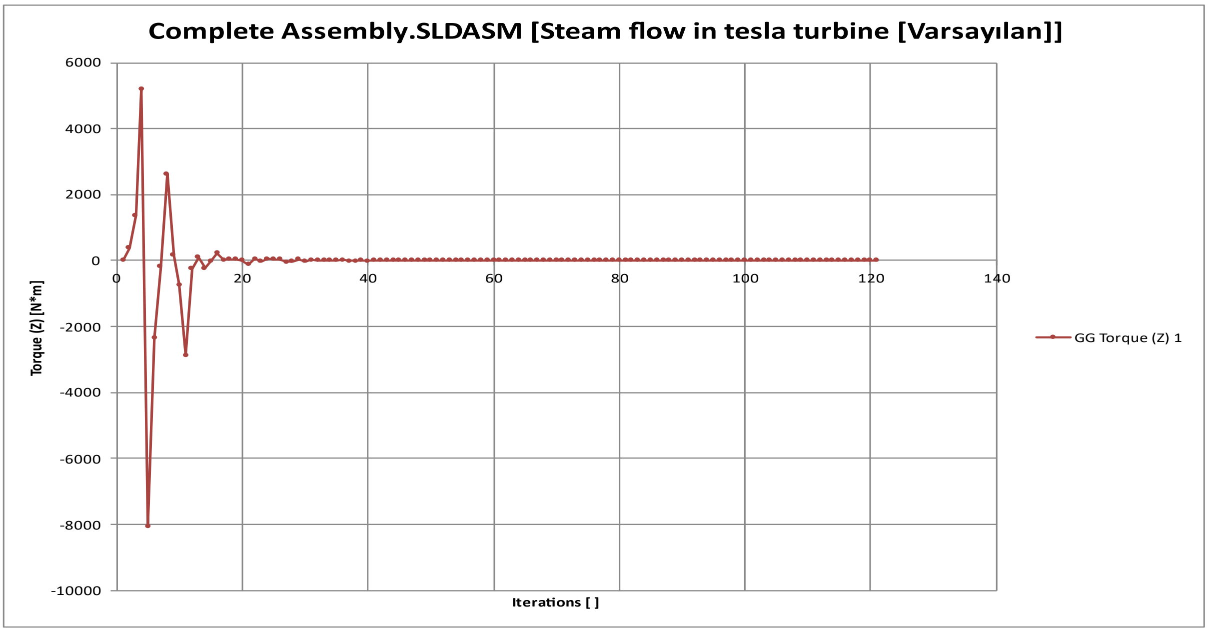

Figure 26: GG Min. Torque (Z) 1 (No-load)

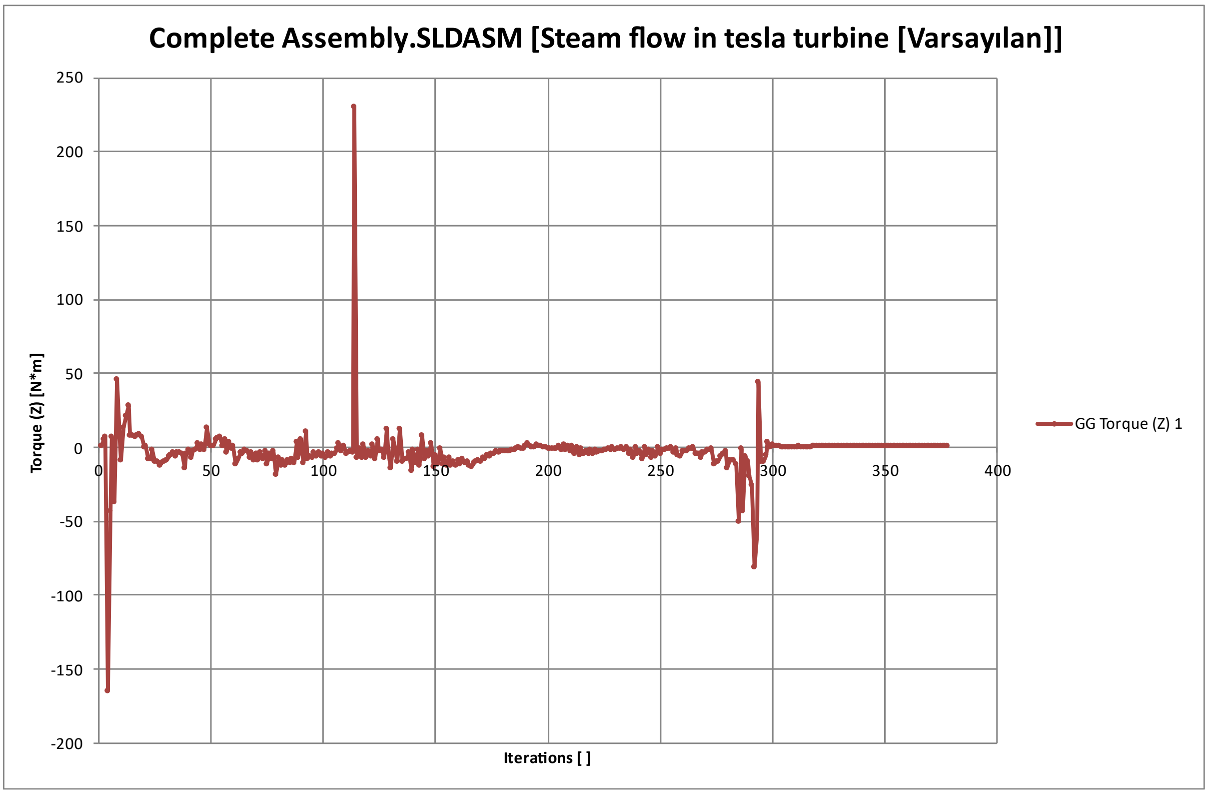

Figure 27: GG Min. Torque (Z) 1 (Full-load)

5.1.4 GG Minimum Shear Stress 1:

The force that causes deformation in the material is known as shear stress. Whenever there is no-load condition, the shear stress will be close to zero because of the fact that there is nothing to be deformed. Consequently, in full-load condition, the shear stress is directly proportional to the load applied. This has been depicted in the graphs below.

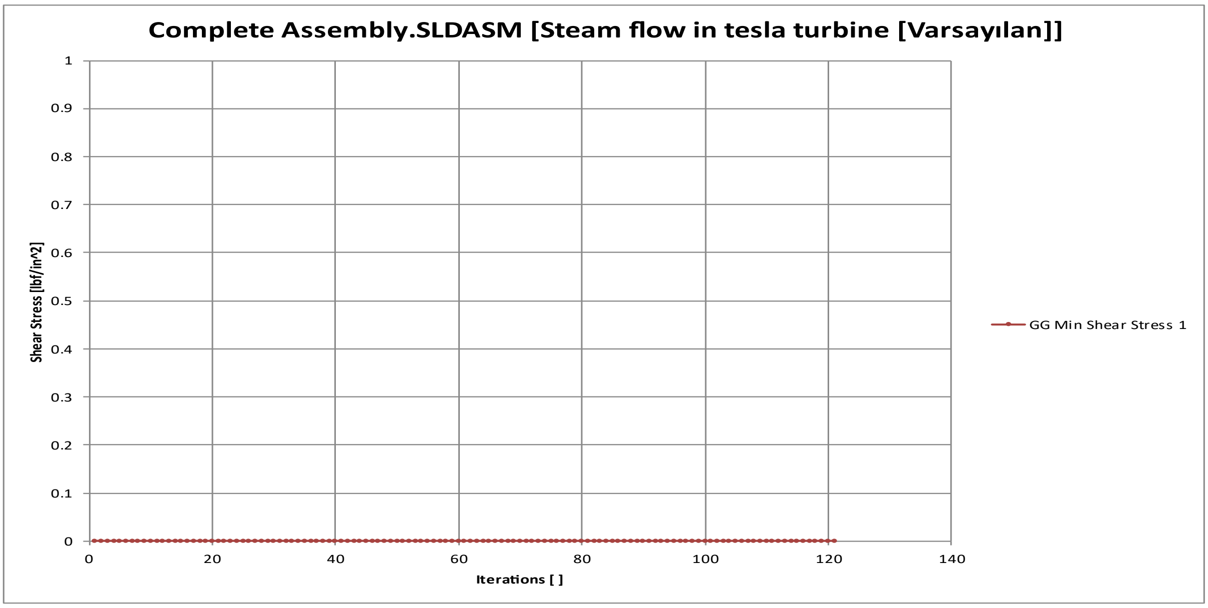

Figure 28: Minimum Shear Stress 1 (No-load)

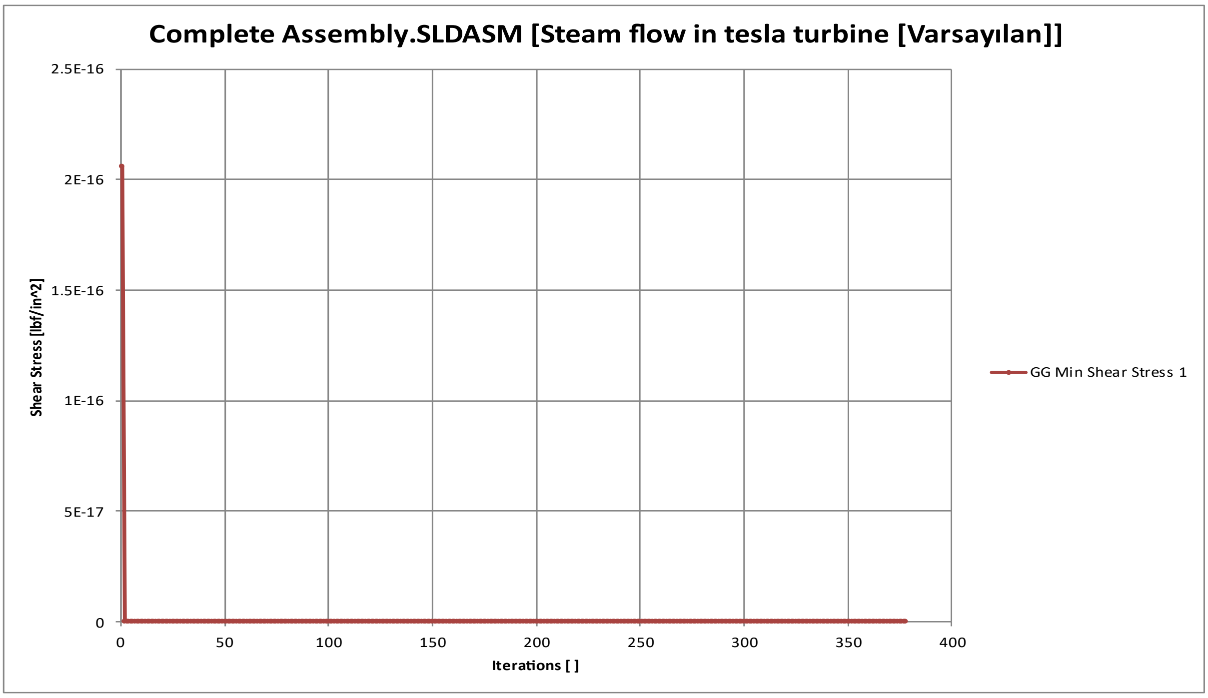

Figure 29: Minimum Shear Stress 1 (Full-load)

5.1.5 GG Minimum Velocity 1:

The minimum velocity is the parameter that drives the system from rest. The initial condition is close to zero for many functions. This has been depicted in the graphs below. The values are almost same for both no-load and full-load condition.

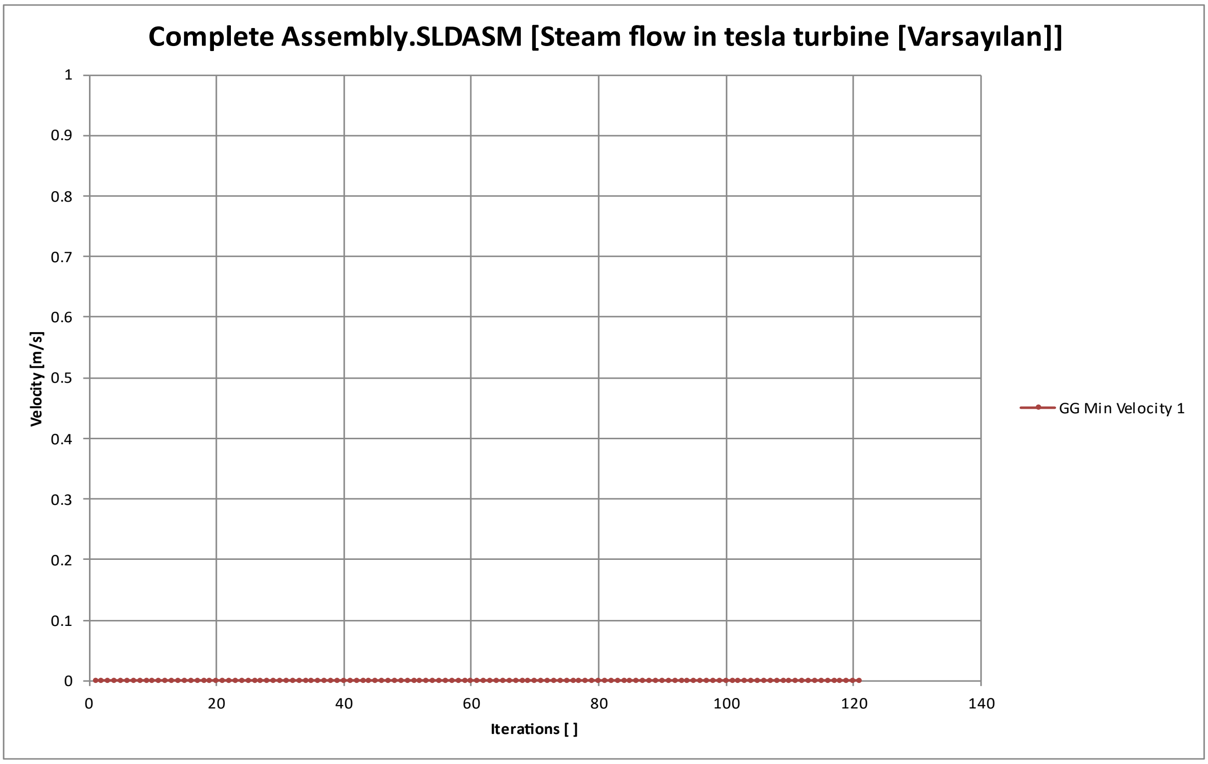

Figure 30: Minimum Velocity 1

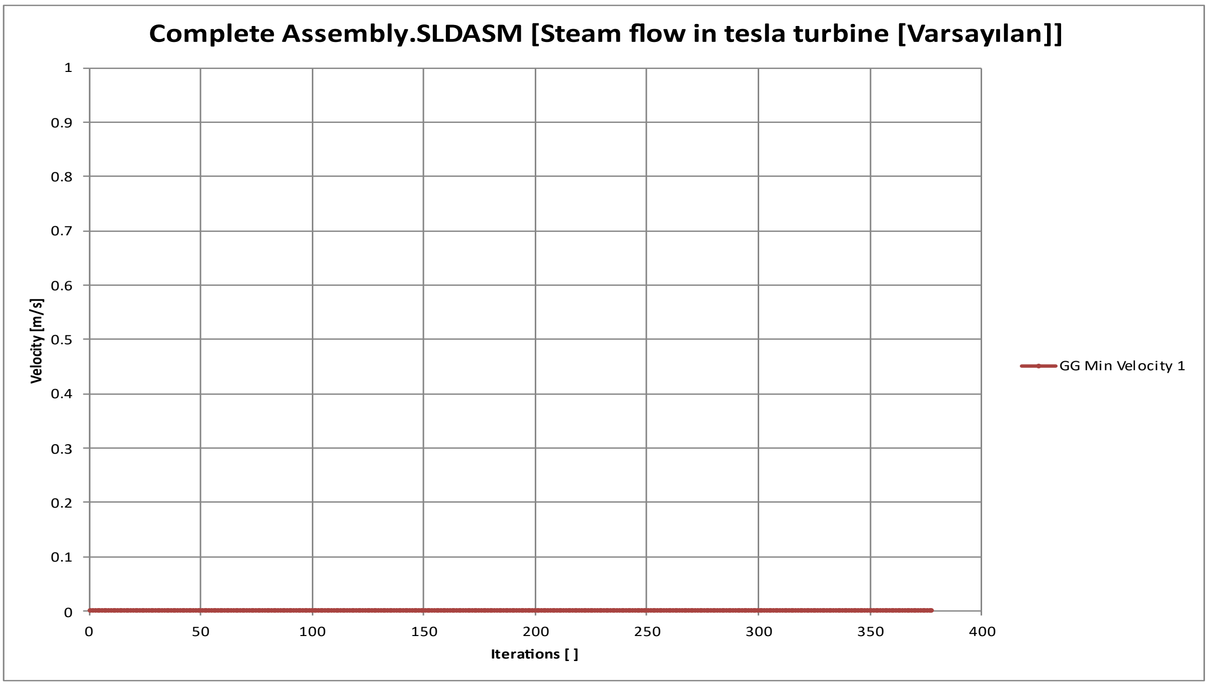

Figure 31: Minimum Velocity 1 (Full-load)

5.1.6 GG Mass Flow Rate 1:

The rate of any liquid passing through a unit area is known as mass flow rate. Since it is dependent on unit area which remains regardless of no-load or full-load, the results are quite similar. The graphs depict this statement.

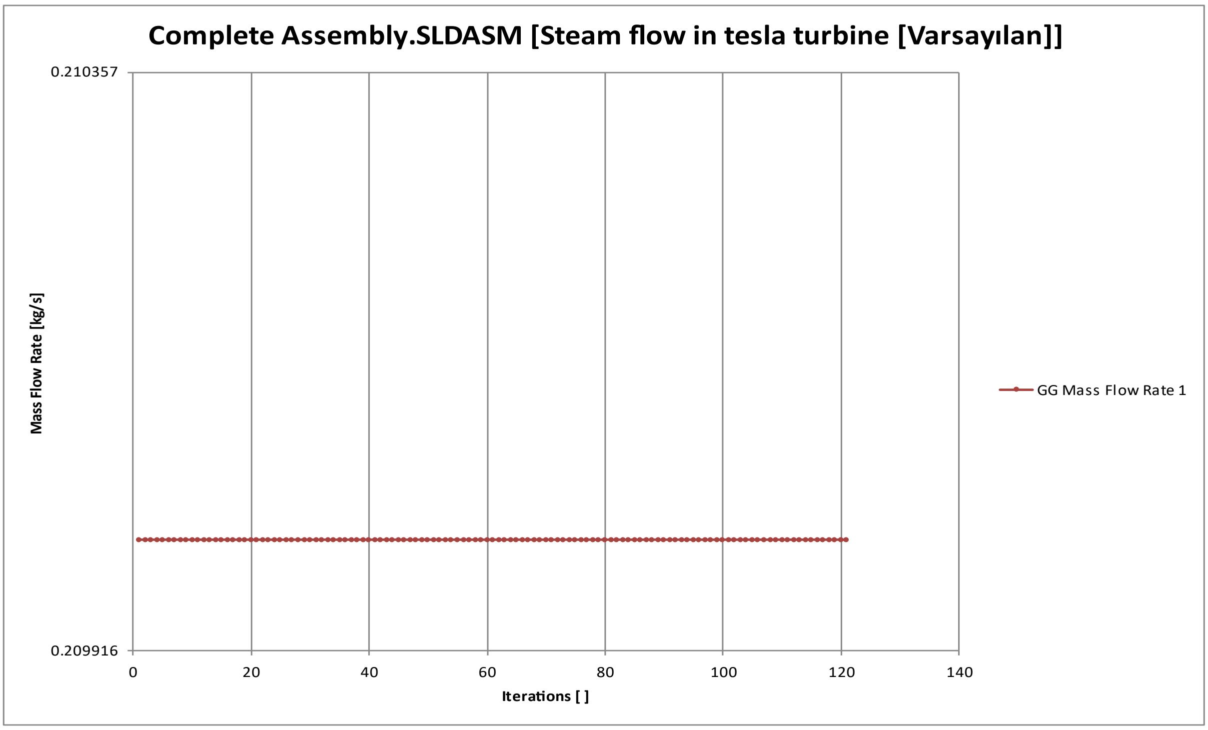

Figure 32: GG Mass flow rate 1 (No-load)

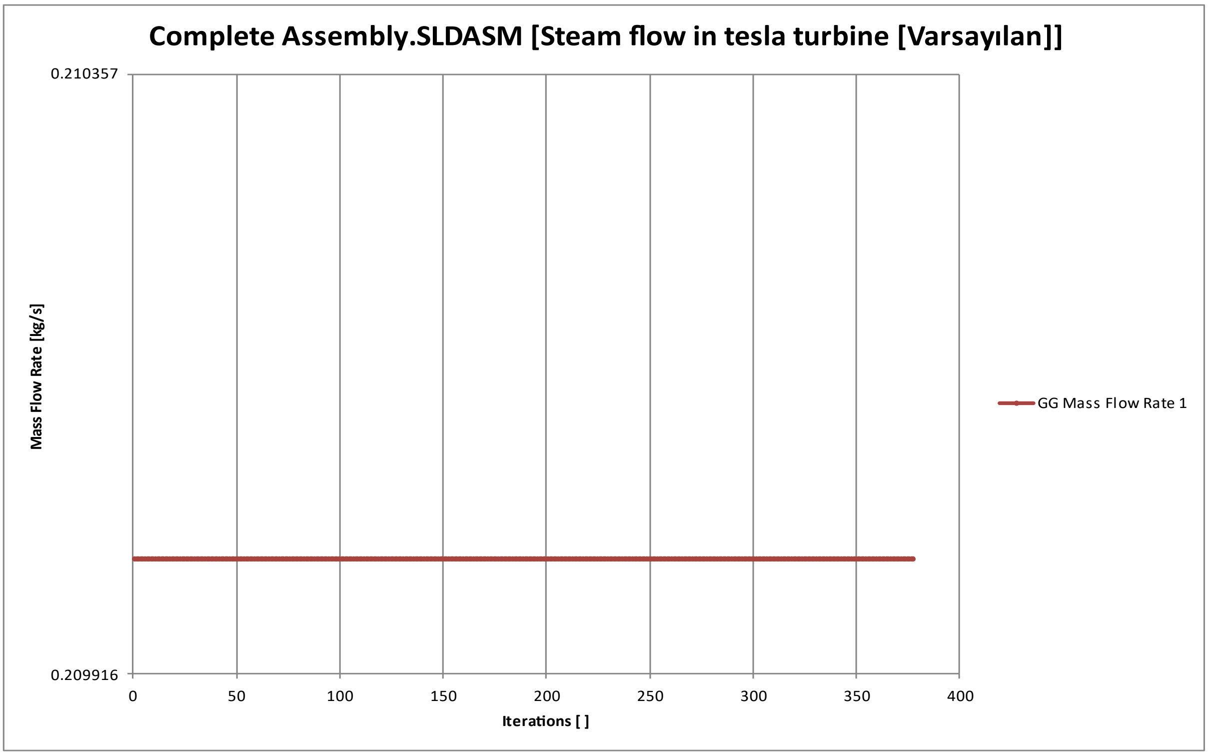

Figure 33: GG Mass flow rate 1 (Full-load)

5.1.7 GG Mass (Fluid) 1:

The increased number of iterations result in the decrease of the mass. There is a sudden rise in the mass at the start in both conditions but after that they drop down close down to their initial conditions.

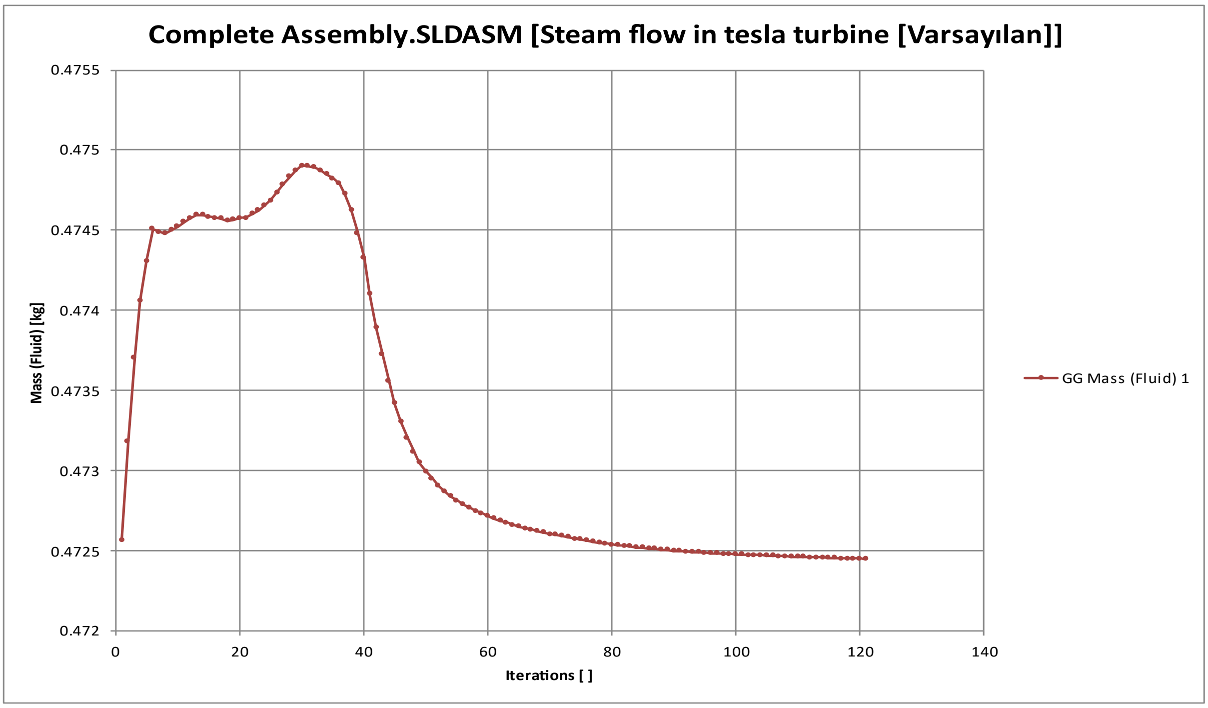

Figure 34: GG Mass (Fluid) 1 (No-load)

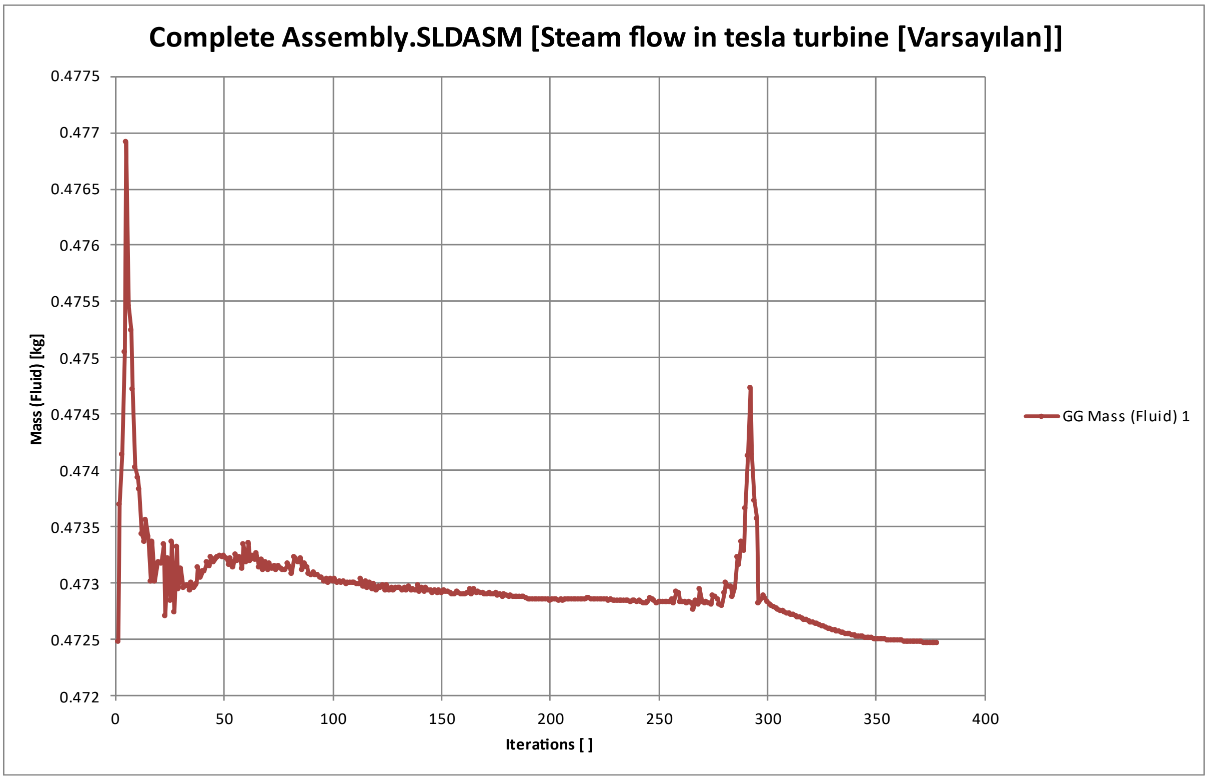

Figure 35: GG Mass (Fluid) 1 (Full-load)

5.1.8 GG Minimum Temperature (Fluid):

Previously, the minimum temperature for the solid was found. This time, it is fluid that is under consideration. The difference between the physical state as compared to the solid, the results were different. In No-load condition, the temperature drops to around -55^{o}C while in full-load, the temperature drops down to around -1100^{o}C. The graphs below depict this better.

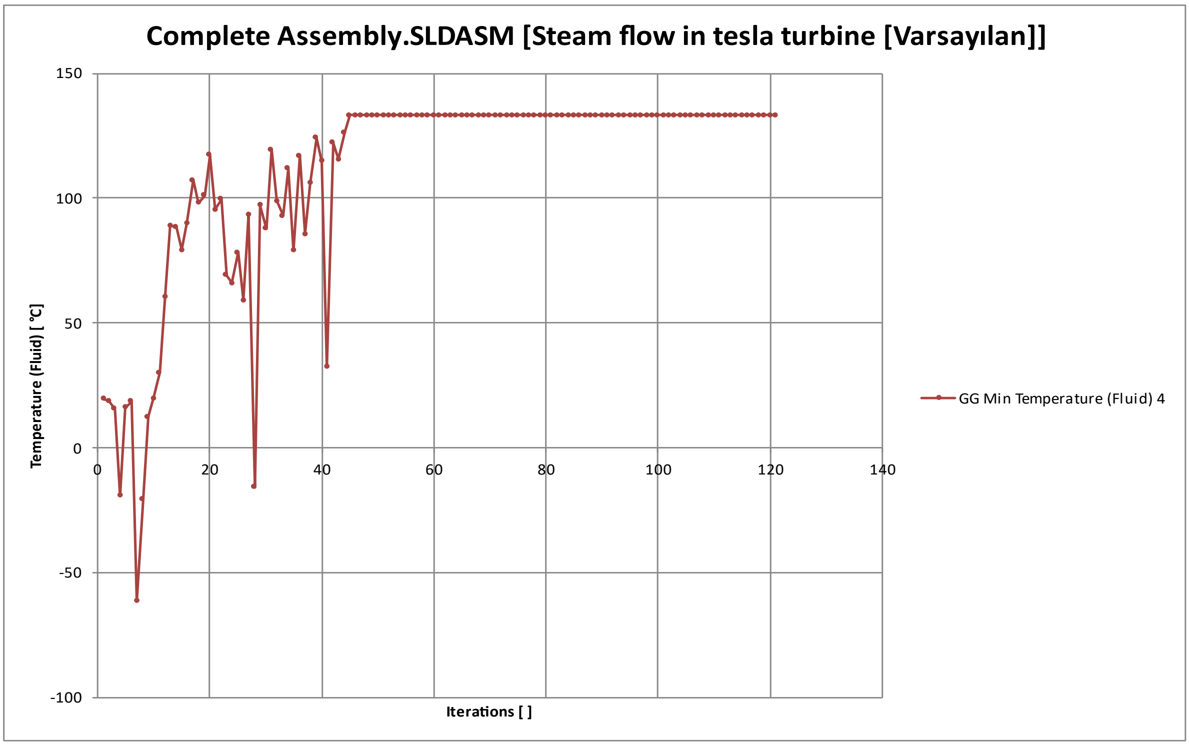

Figure 36: GG Minimum Temperature (Fluid) (No-load)

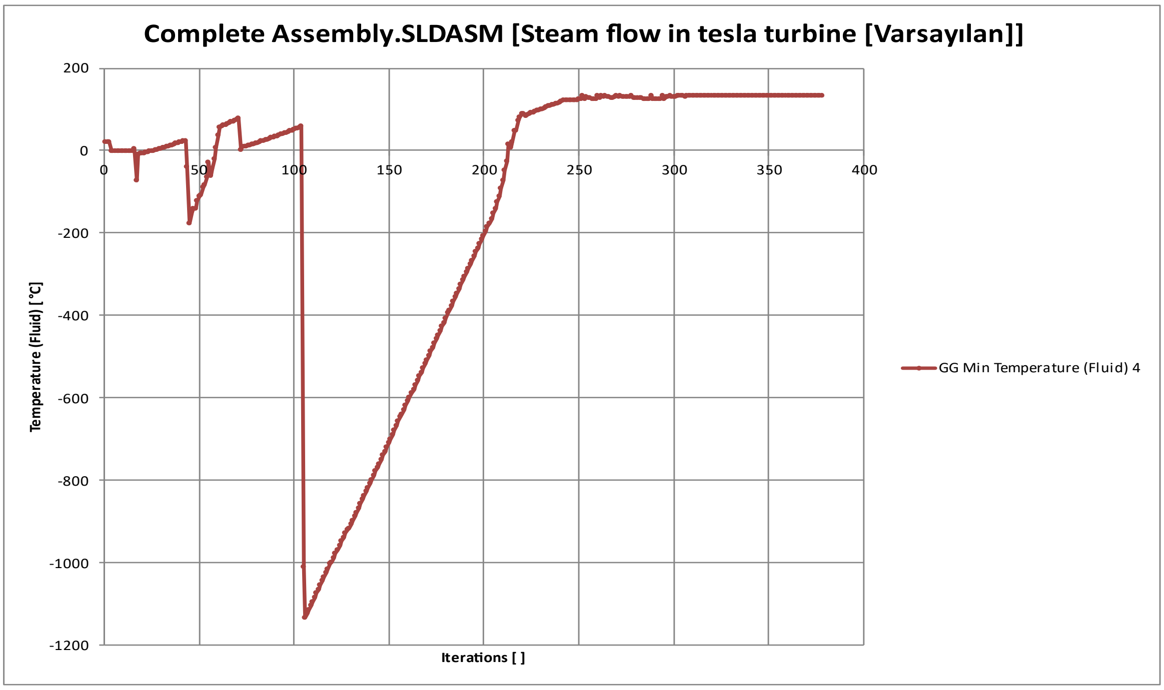

Figure 37: GG Minimum Temperature (Fluid) (Full-load)

5.1.9 GG Minimum Dynamic Pressure 4:

The minimum pressure for both conditions remain same. The reason is because this is an external element that can be changed by the user according to the requirements. No-load and full-load conditions have almost same result that is shown in the graphs below.

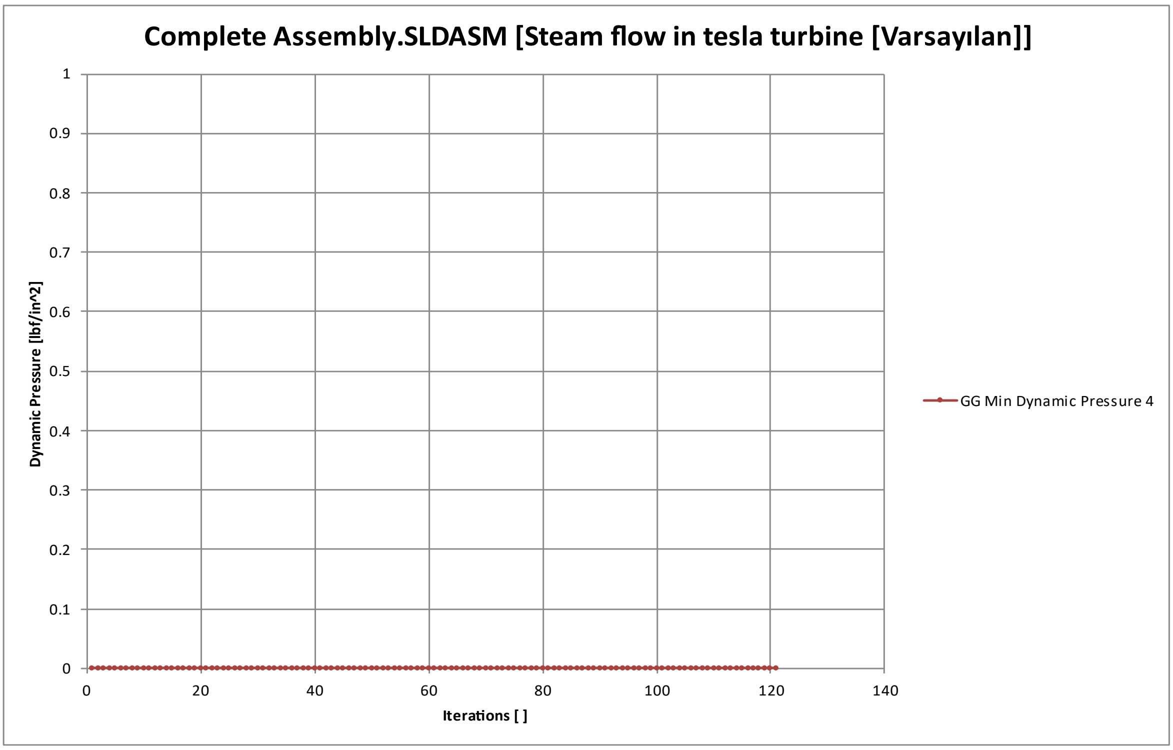

Figure 38: GG Minimum Dynamic Pressure 4 (No-load)

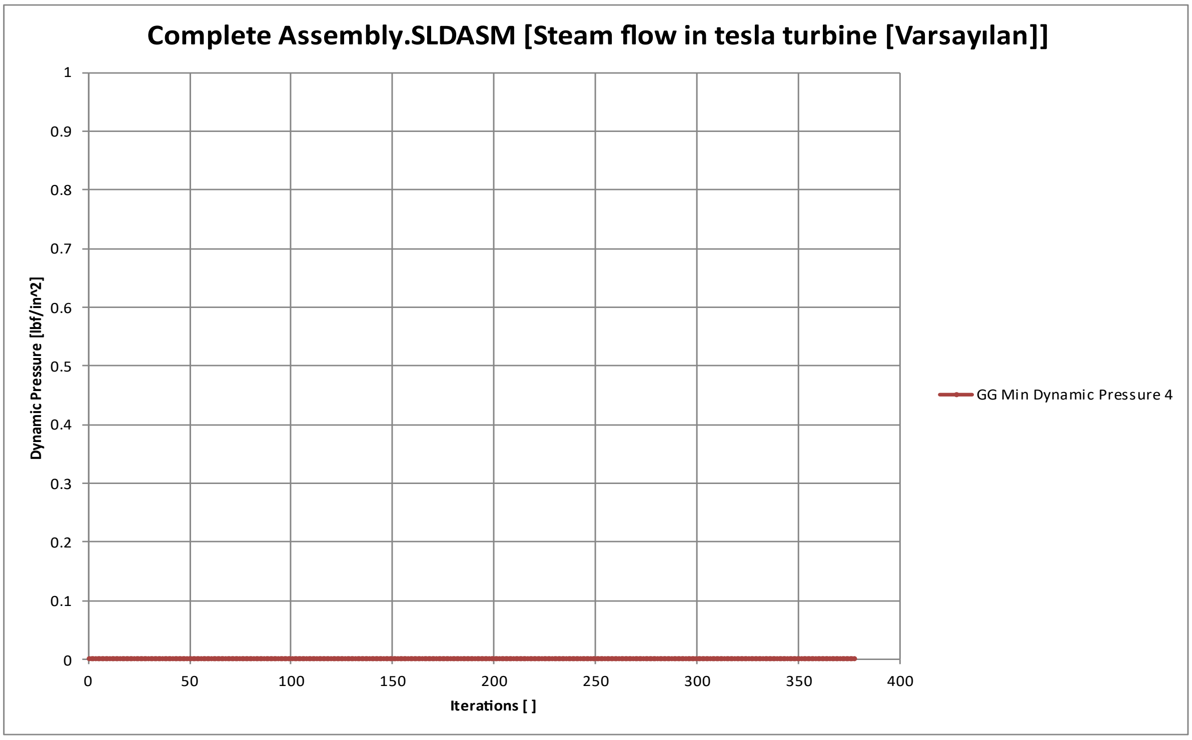

Figure 39: GG Minimum Dynamic Pressure 4 (Full-load)

5.1.10 GG Minimum Total pressure 4:

As already discussed, total pressure remains almost same on both conditions i.e., no load and full load. The graphs below depict the same thing. This means that when load is applied, the minimum total pressure doesn't change much.

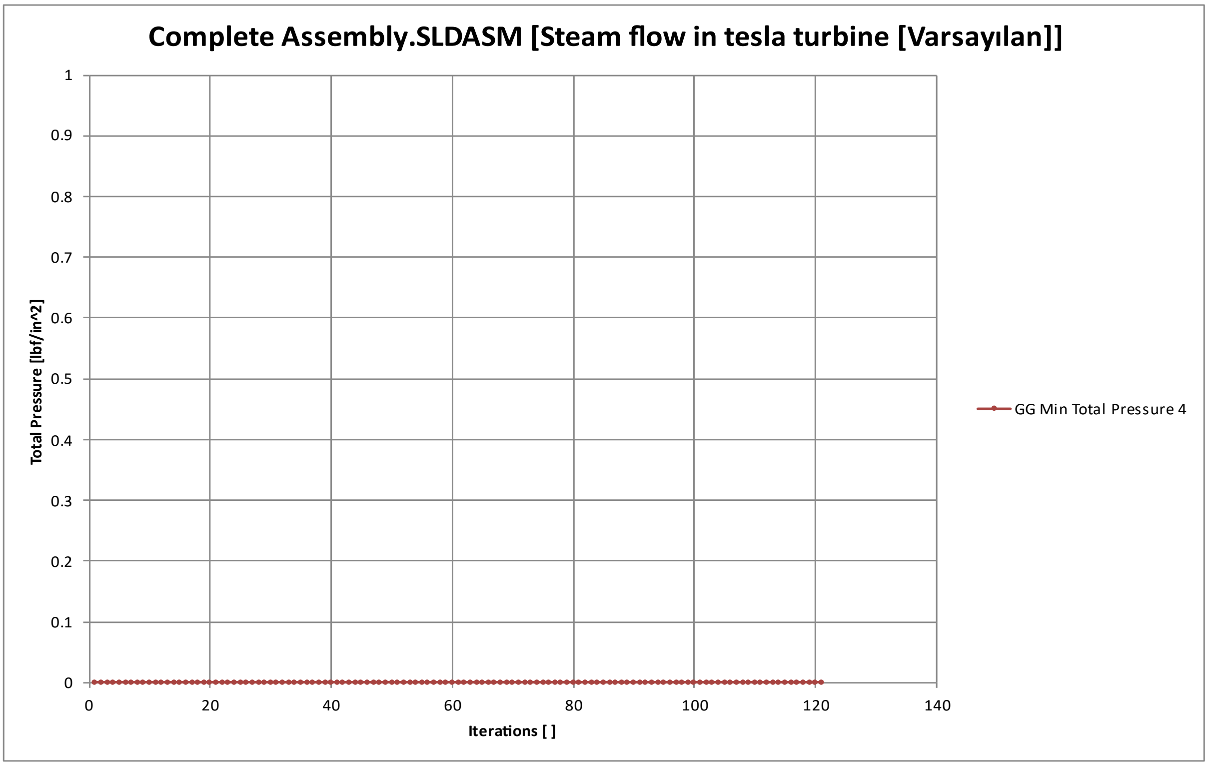

Figure 40: GG Minimum total pressure 4 (No-load)

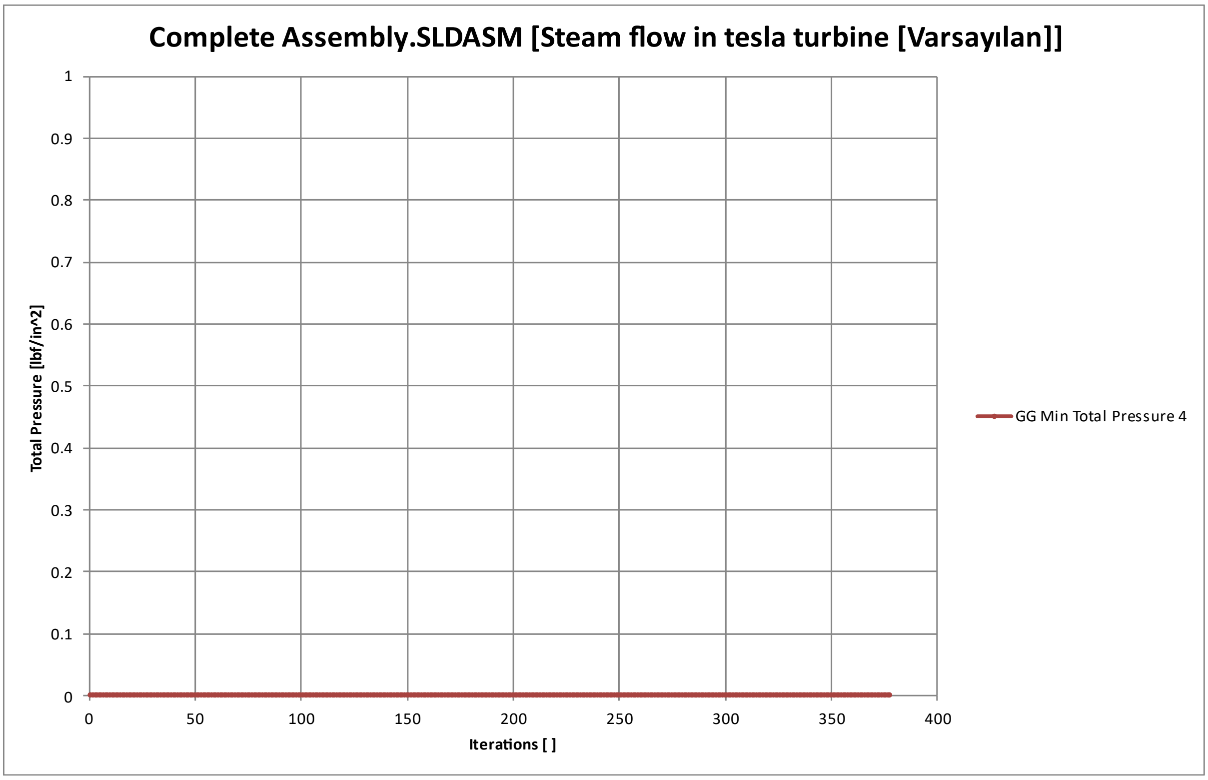

Figure 41: GG Minimum total pressure 4 (Full-load)

5.1.11 GG Minimum Static Pressure 4:

There is a difference in minimum static pressure in both conditions. When the load is applied, there is abruption in systems which can be seen in the graph while in no-load condition, the abruption is quite less. There comes a point where it becomes quite stable in no-load condition.

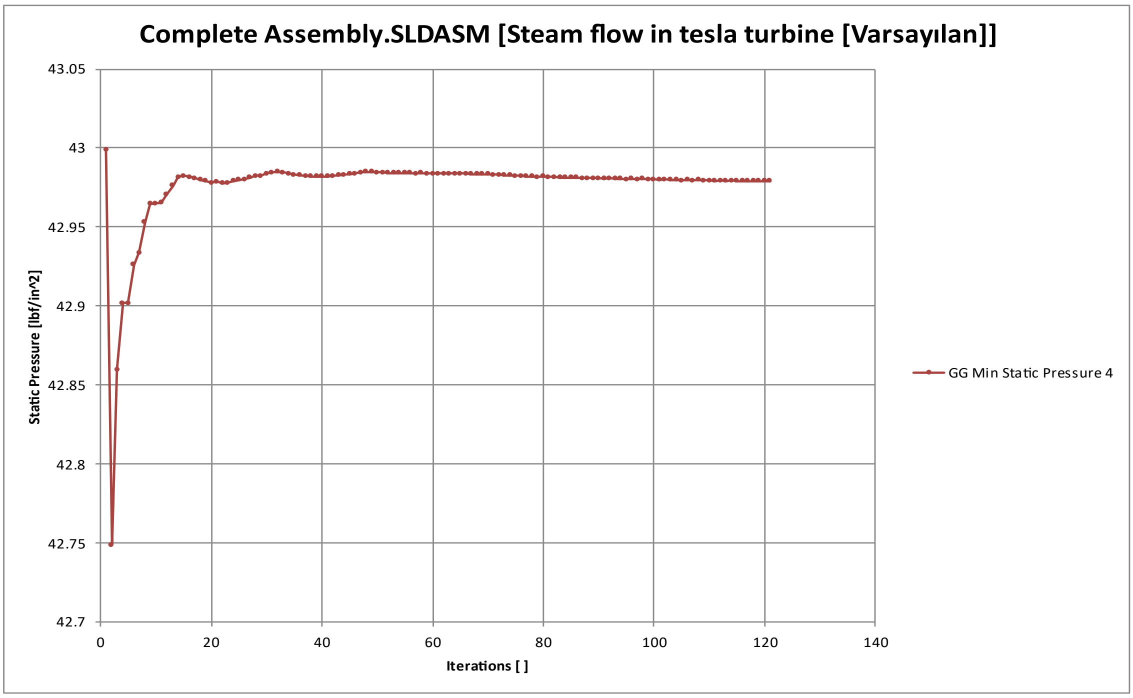

Figure 42: GG Minimum Static Pressure 4 (No-load)

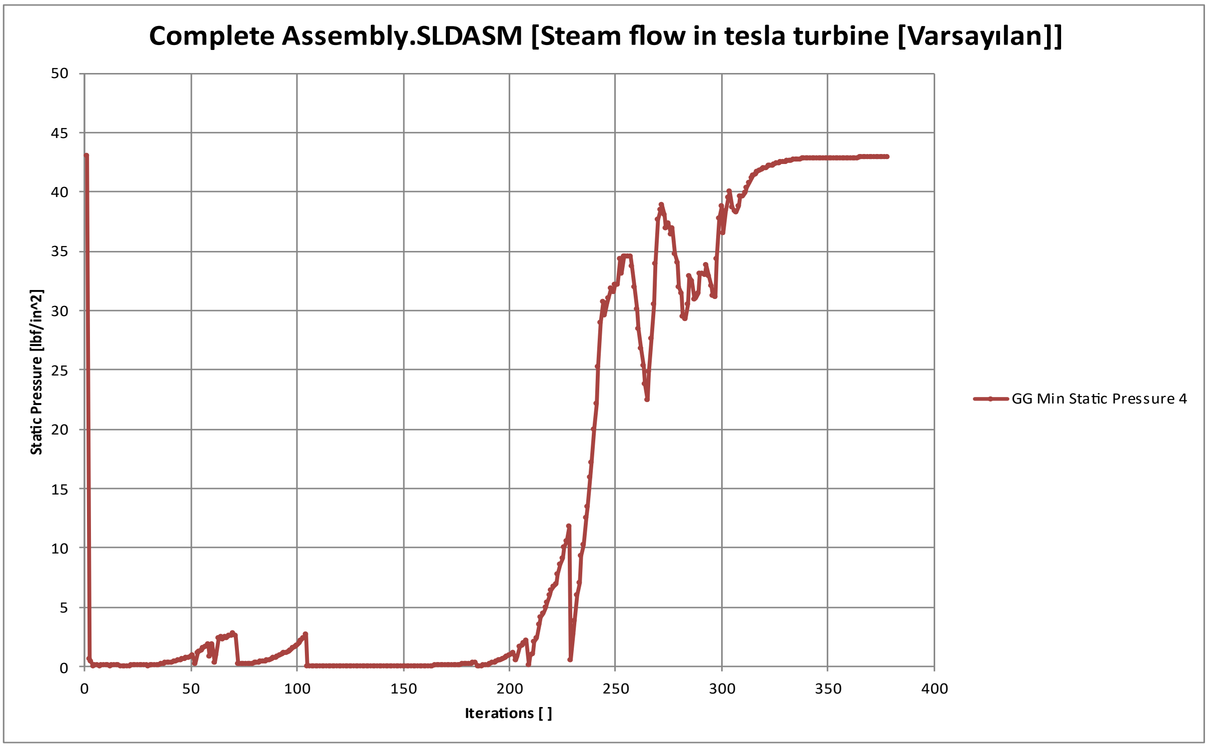

Figure 43: GG Minimum Static Pressure 4 (Full-load)

5.1.12 GG Minimum Temperature (Fluid) 3:

This is third experiment where we are finding out the minimum temperature of the fluid. The results are somewhat related to what we did previously. The temperature drops down same levels as previously it did.

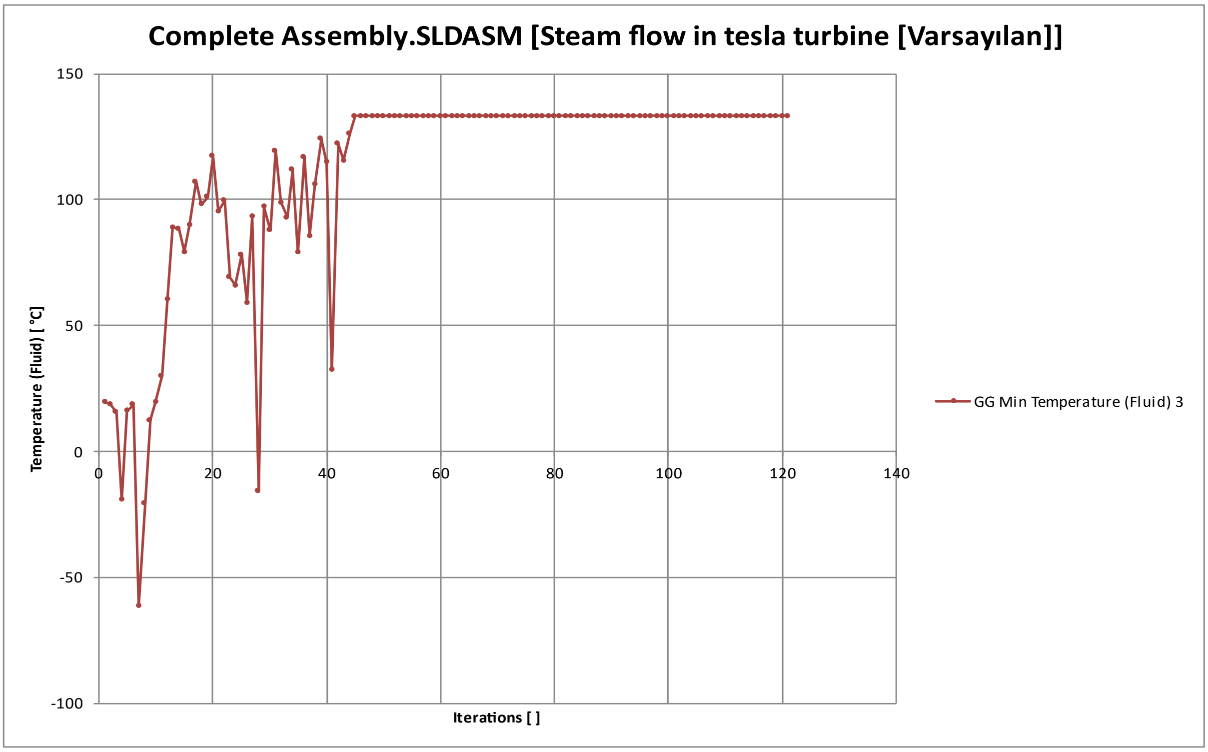

Figure 44: GG Minimum Temperature (Fluid) 3 (No-load)

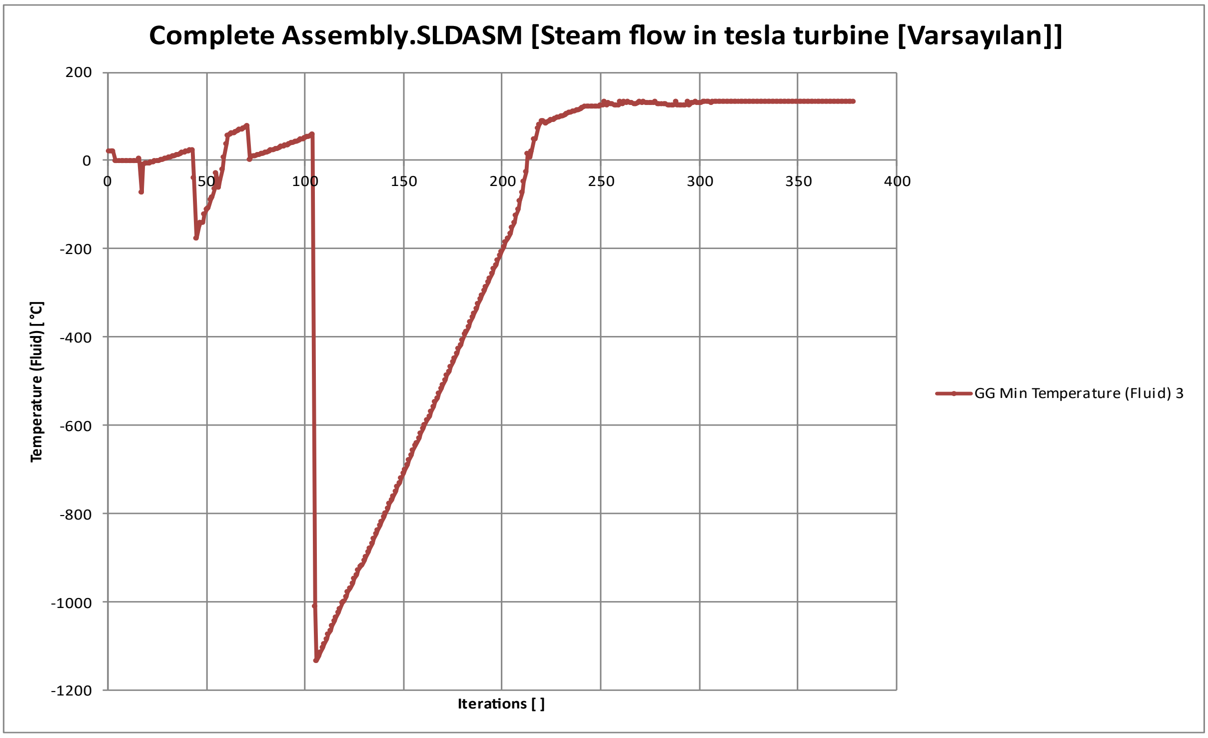

Figure 45: GG Minimum Temperature (Fluid) 3 (Full-load)

5.1.13 GG Minimum Dynamic Pressure 3:

Third time is the charm. But even third time, the minimum dynamic pressure remains the same in both conditions.

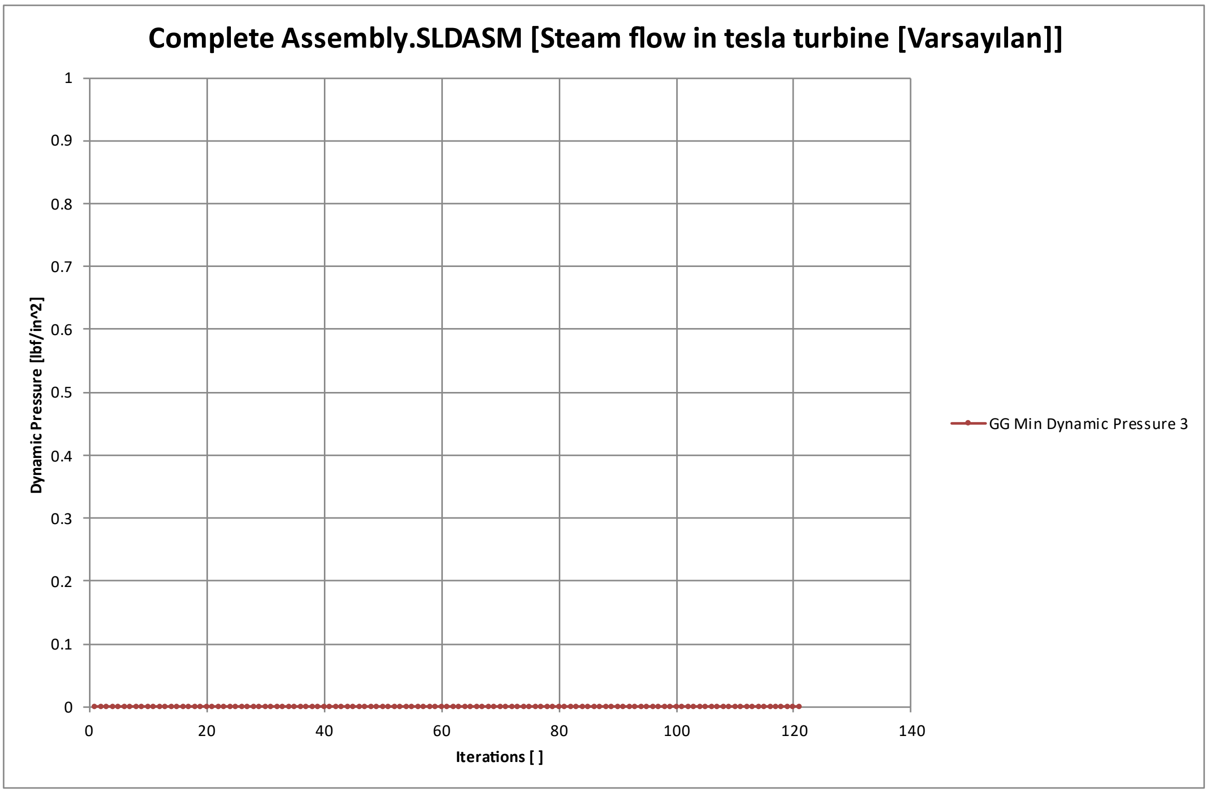

Figure 46: GG Minimum Dynamic Pressure 3 (No-load)

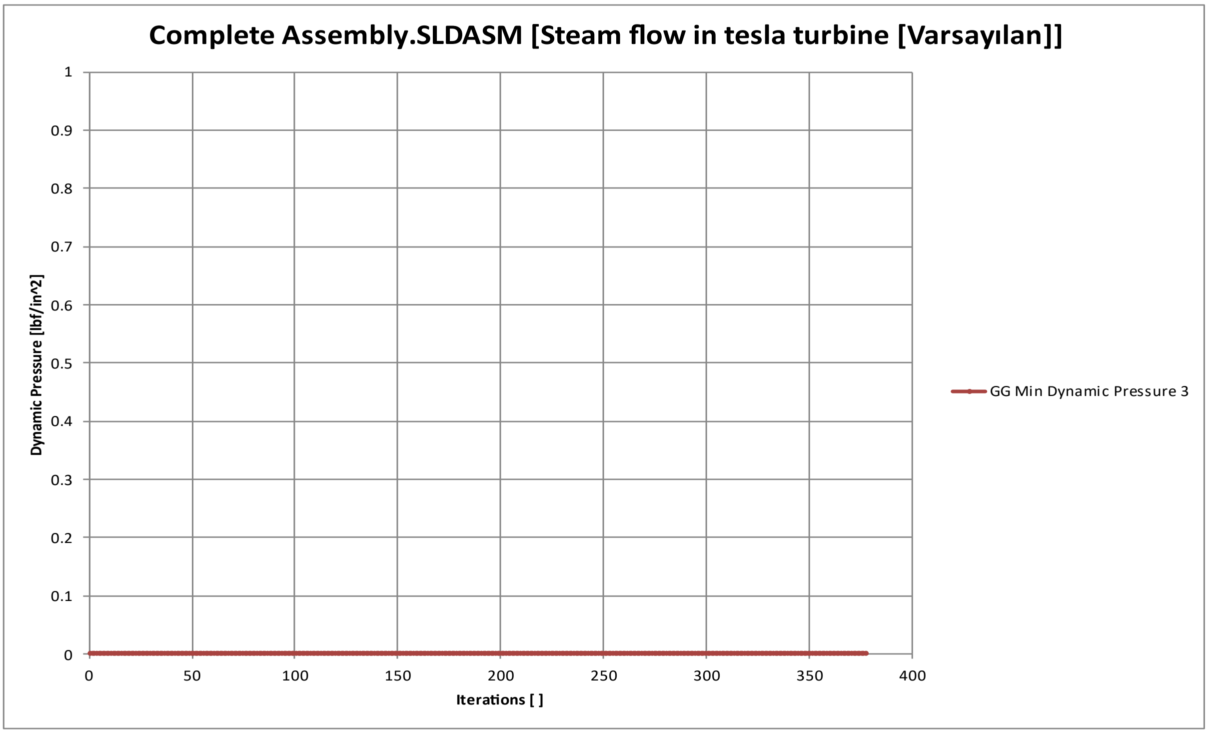

Figure 47: GG Minimum Dynamic Pressure 3 (Full-load)

5.1.14 GG Minimum Total Pressure 3:

The total pressure remains the same in this case as well. Load has not much affect on the pressures present the system.

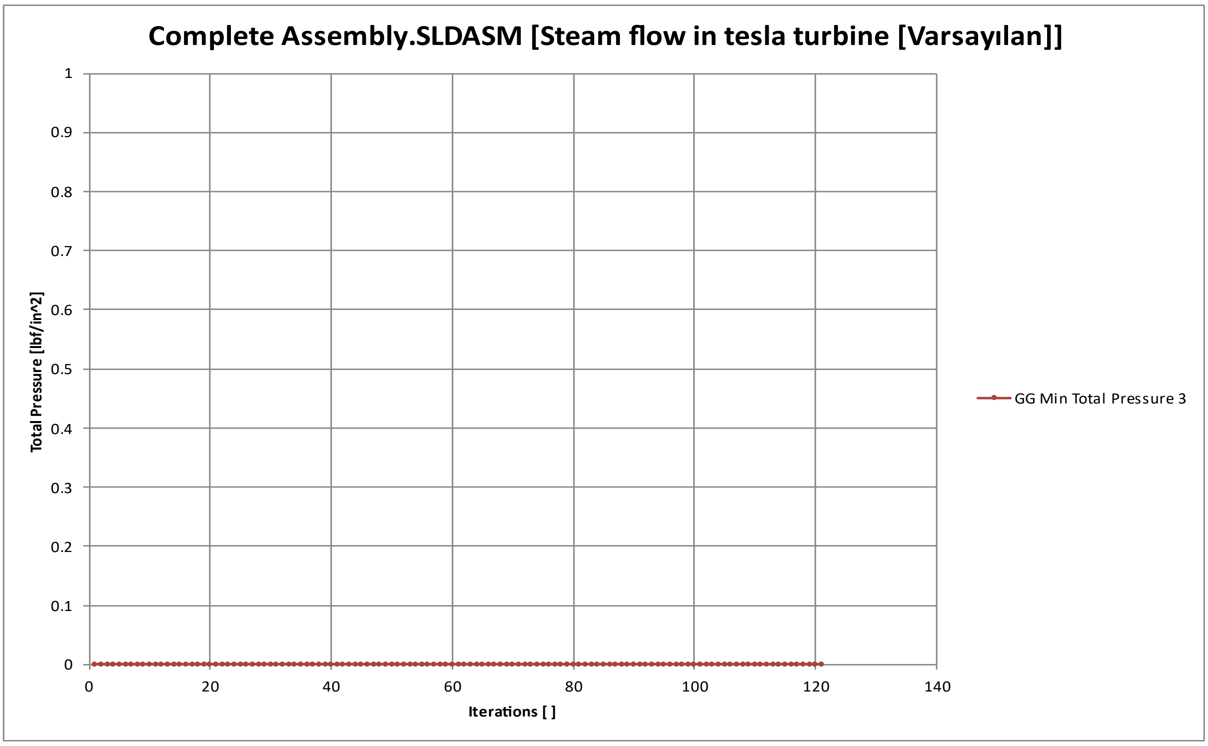

Figure 48: GG Minimum Total pressure 3 (No-load)

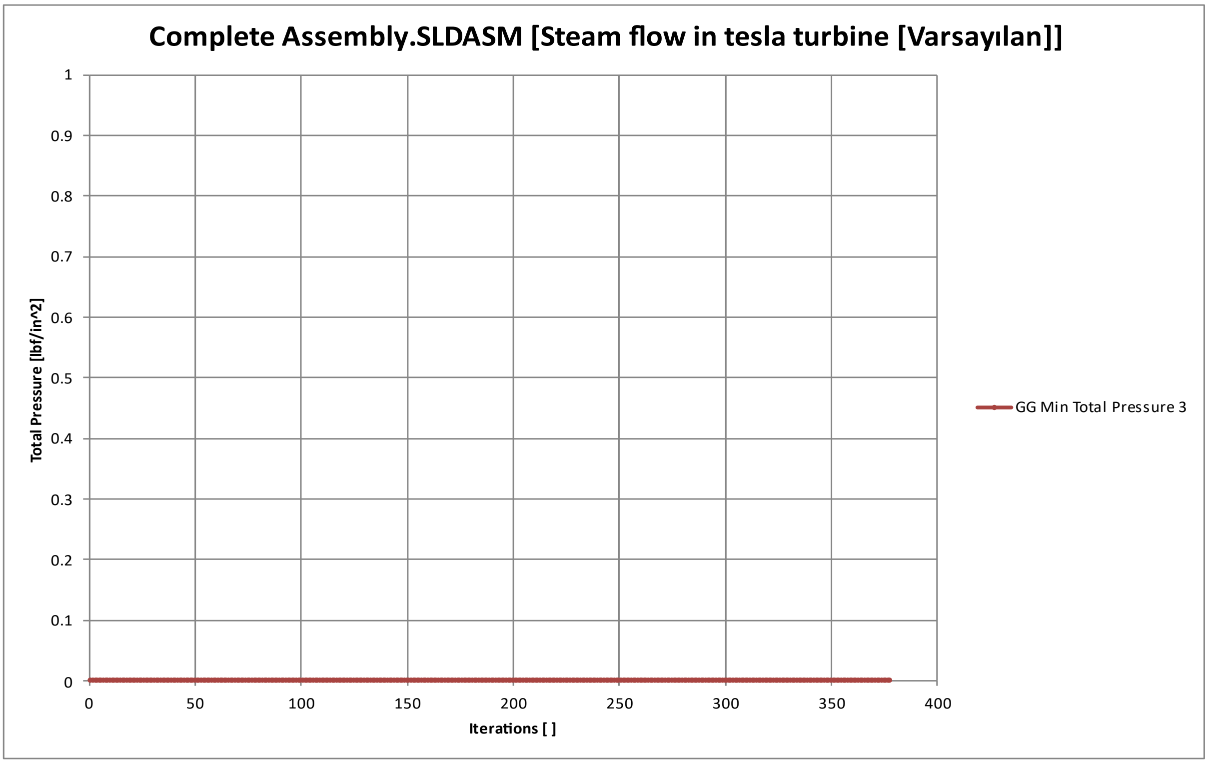

Figure 49: GG Minimum Total Pressure 3 (Full-load)

5.1.15 GG Minimum Static Pressure 3:

This is the only parameter in the pressure category that changes in both no-load and full-load conditions. It is because when the load is applied, the static pressure is not easy to maintain. That is why you see disruptions in the graphs as well.

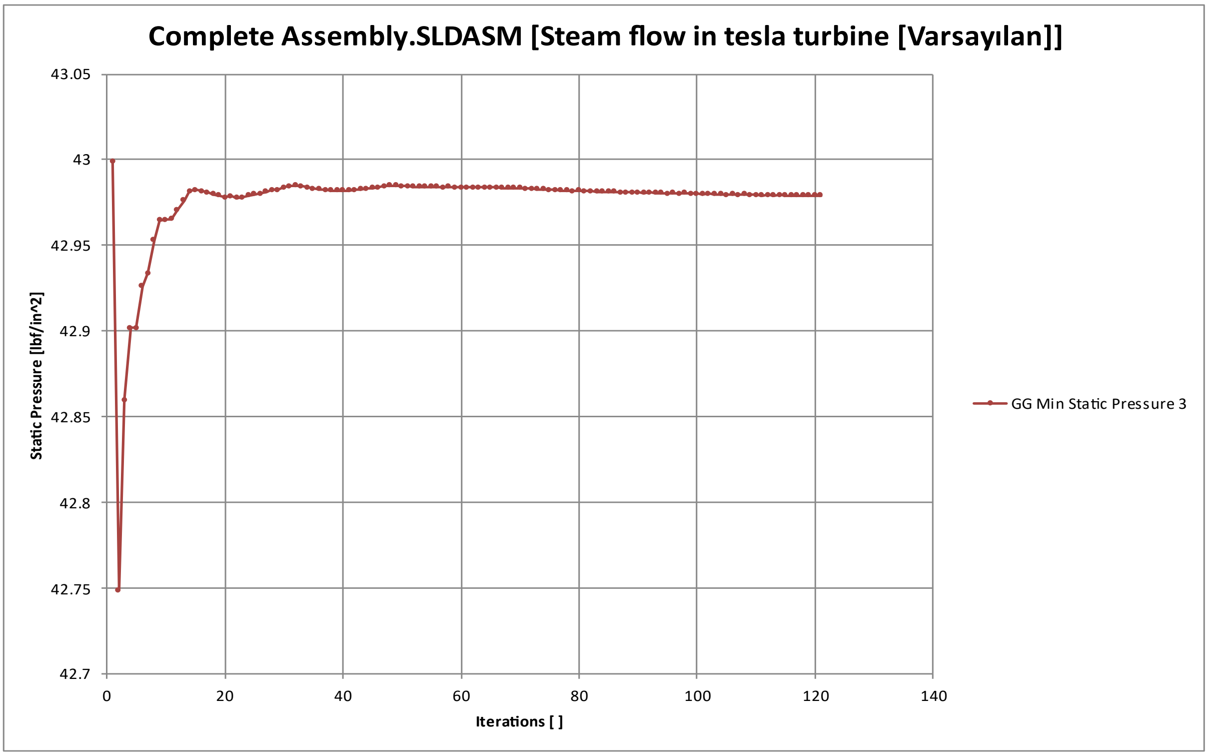

Figure 50: GG Minimum Static Pressure 3 (No-load)

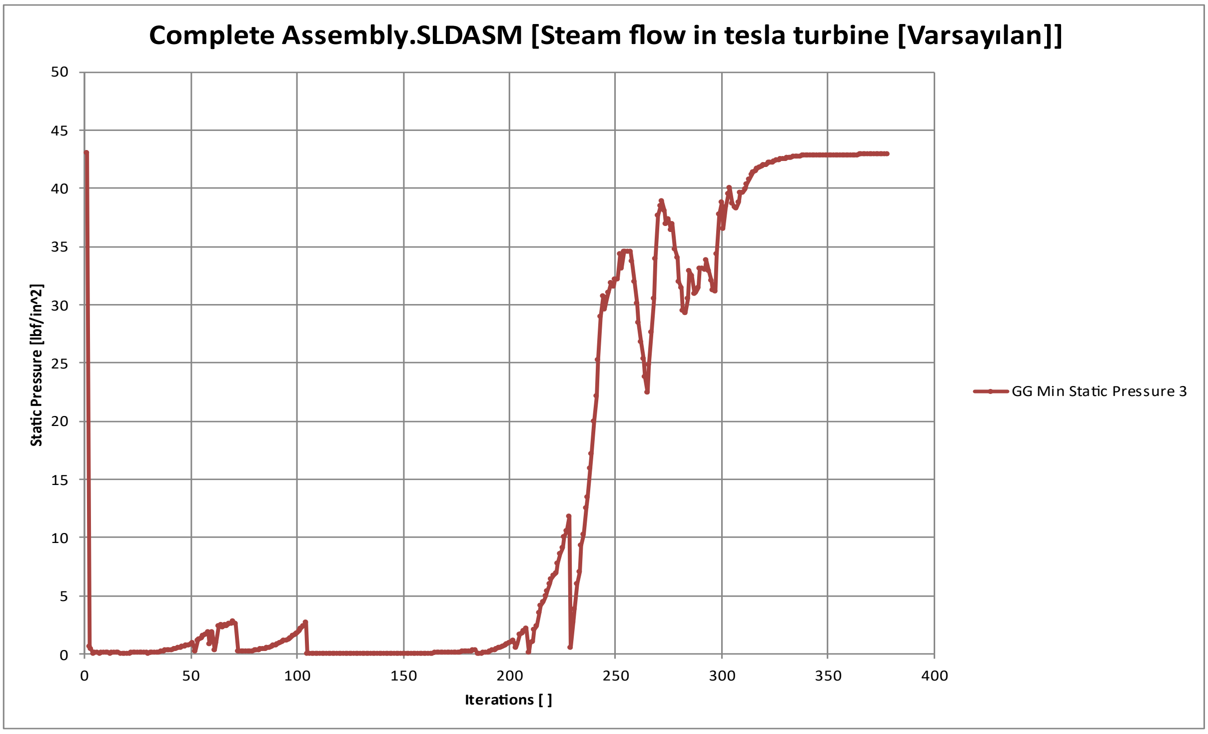

Figure 51: GG Minimum Static Pressure 3 (Full-load)

5.1.16 GG Minimum Temperature (Fluid) 2:

The minimum temperature results are almost same as before. The lower value is almost the same as previous in both no-load and full-load conditions. The disruption s although somewhat different.

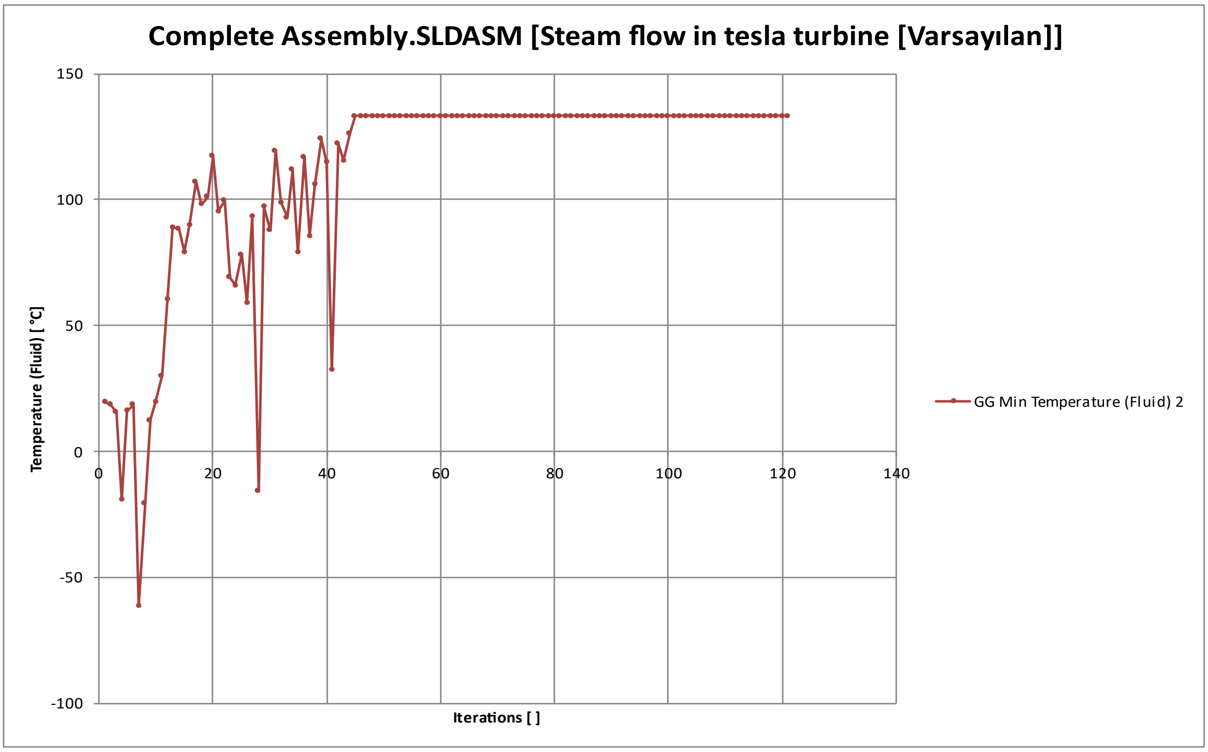

Figure 52: GG Minimum Temperature (Fluid) 2 (No-load)

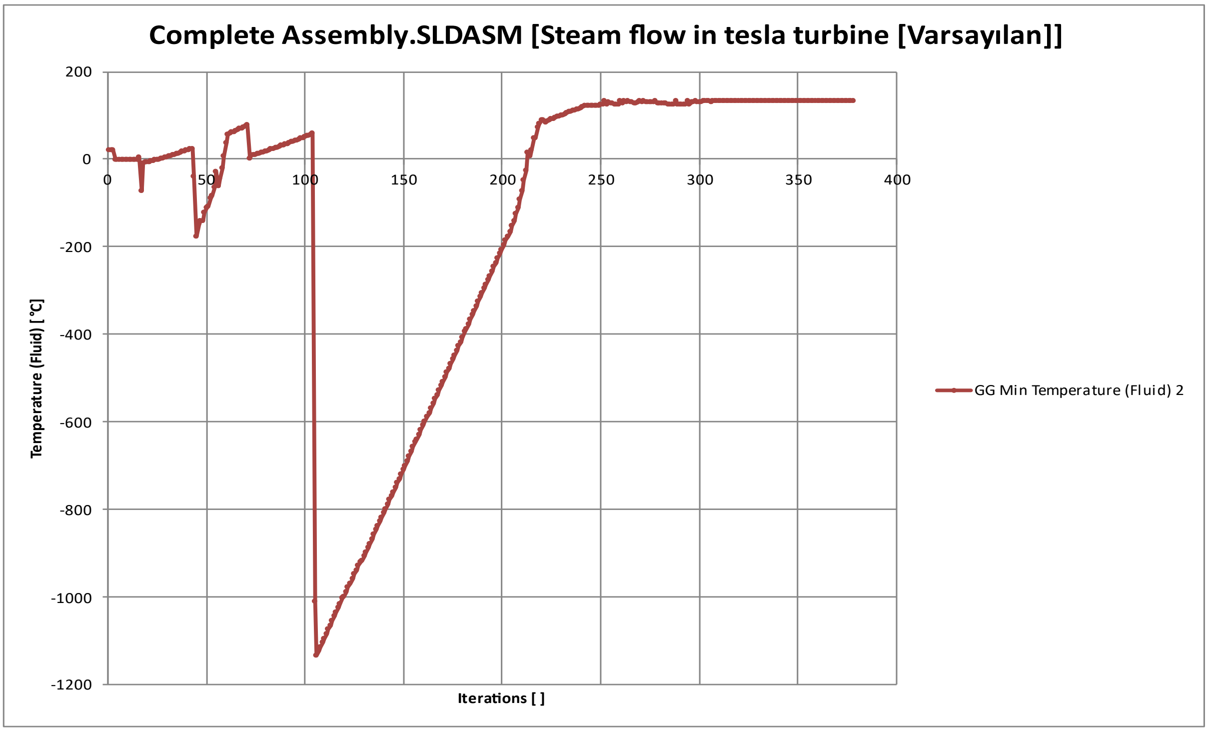

Figure 53: GG Minimum Temperature (Fluid) 2 (Full-load)

5.1.17 GG Minimum Dynamic Pressure 2:

As already discussed, and showed, the pressure doesn't change much in both conditions. This statement is true in this case as well.

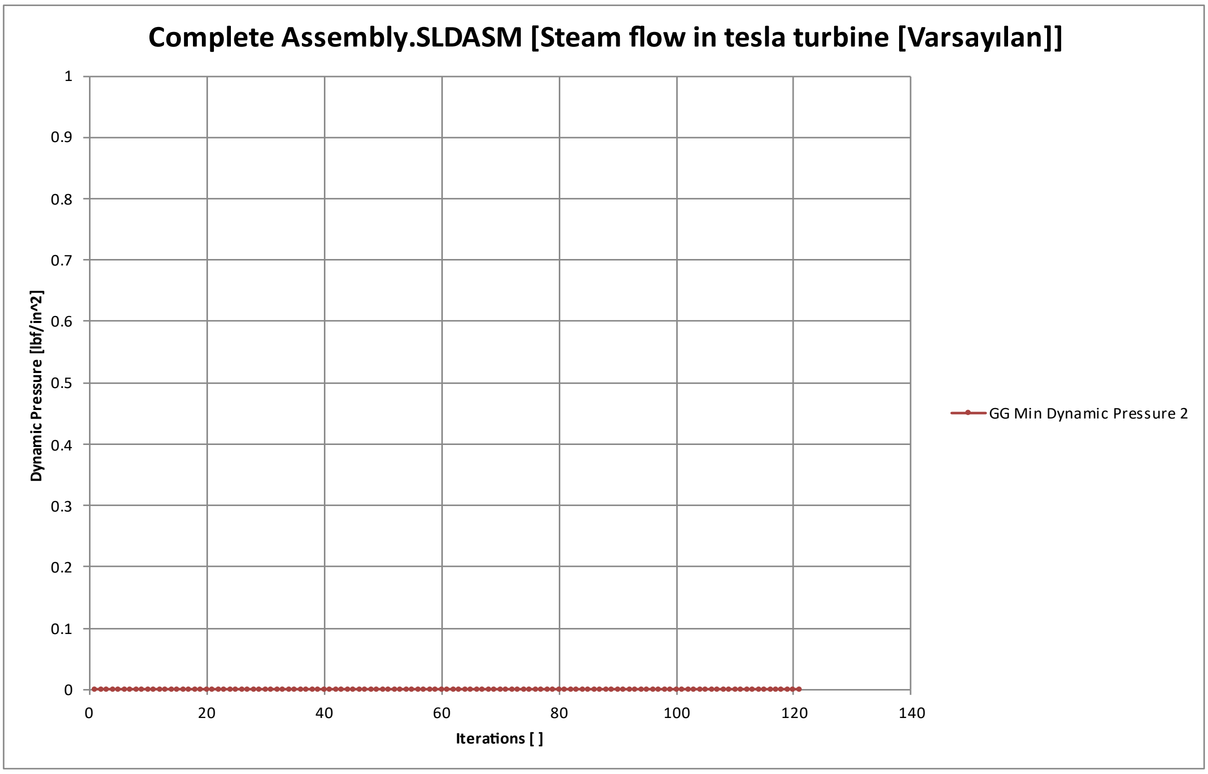

Figure 54: GG Minimum Dynamic Pressure 2 (No-load)

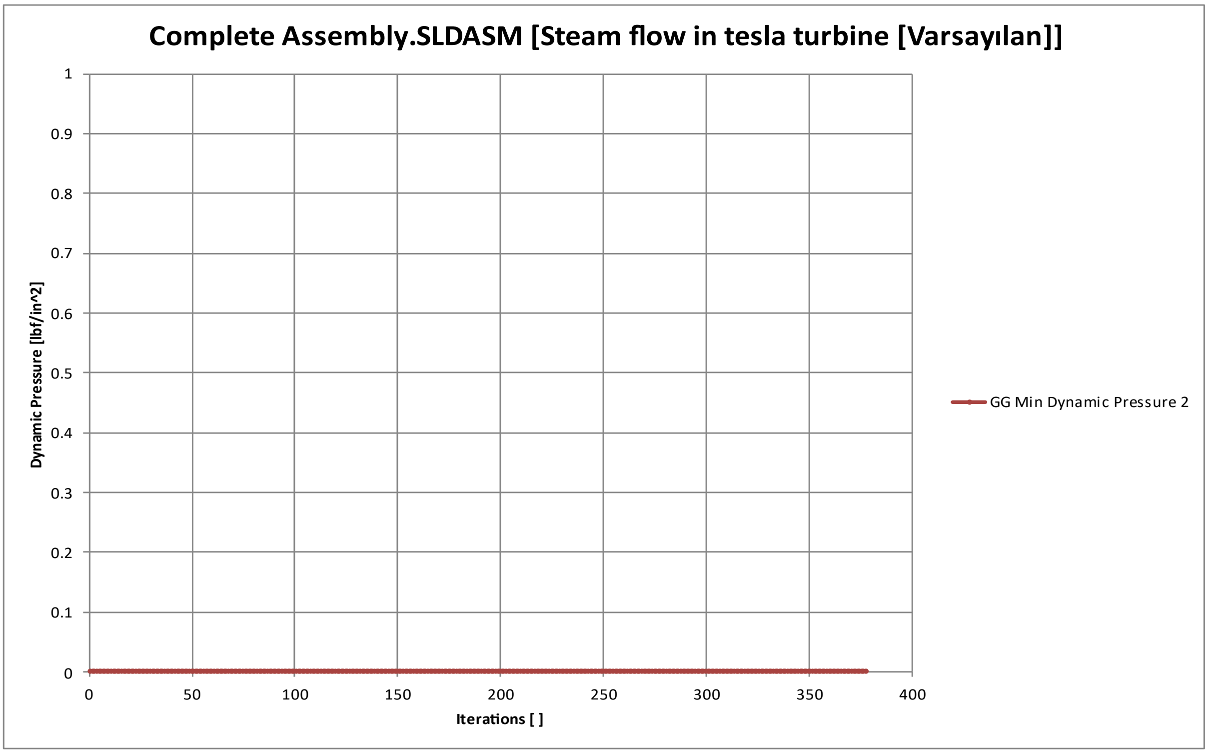

Figure 55: GG Minimum Dynamic Pressure 2 (Full-load)

5.1.18 GG Minimum Total Pressure 2:

This parameter is same and already discussed previously. The stability and equality in both conditions is almost same.

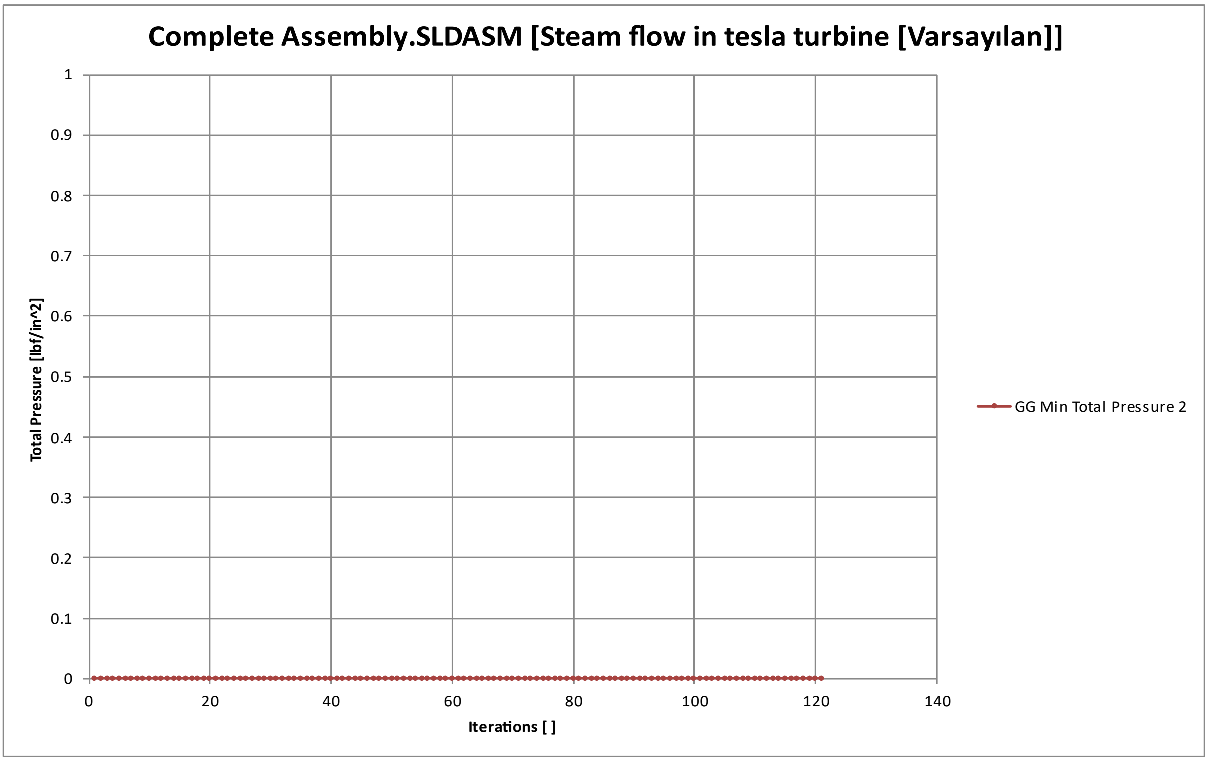

Figure 56: GG Minimum Total Pressure 2 (No-load)

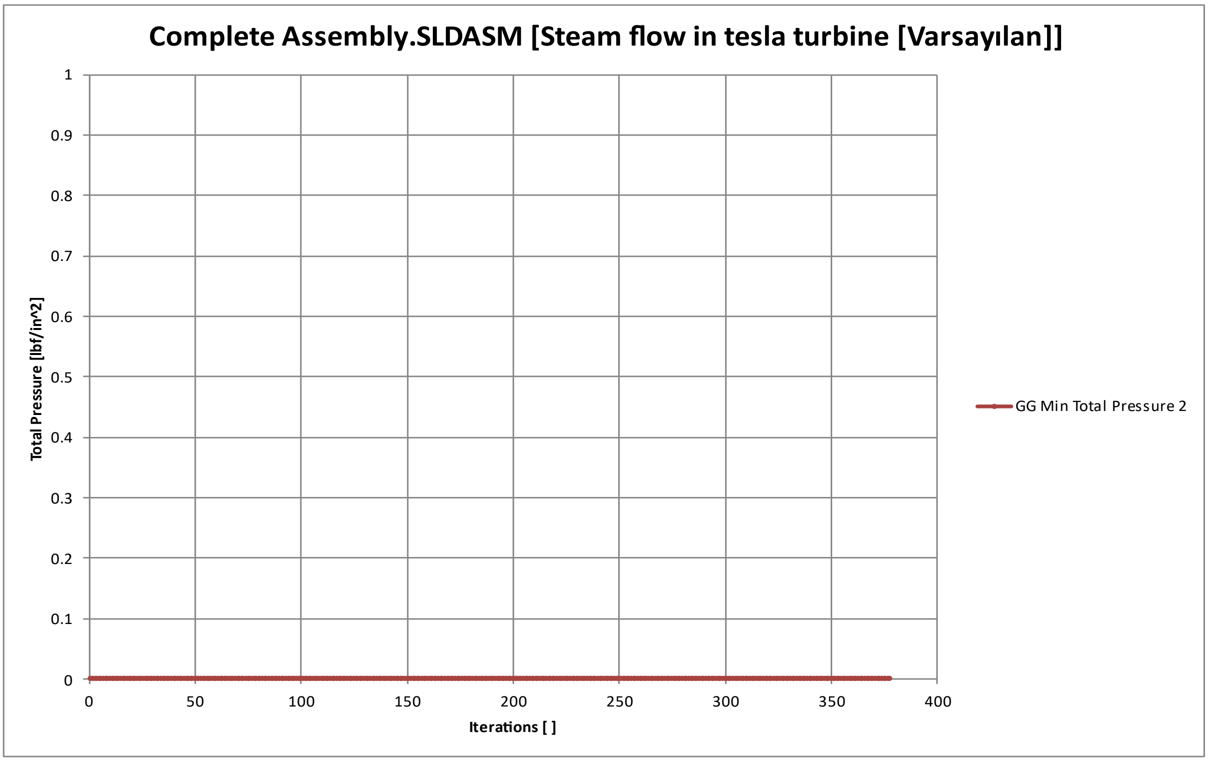

Figure 57: GG Minimum Total Pressure 2 (Full-load)

5.1.19 GG Minimum Static Pressure 2:

As already discussed, and seen, the only pressure that changes is the minimum static pressure. Even in the full-load iteration, the disruptions can be seen clearly which are greater than no-load condition.

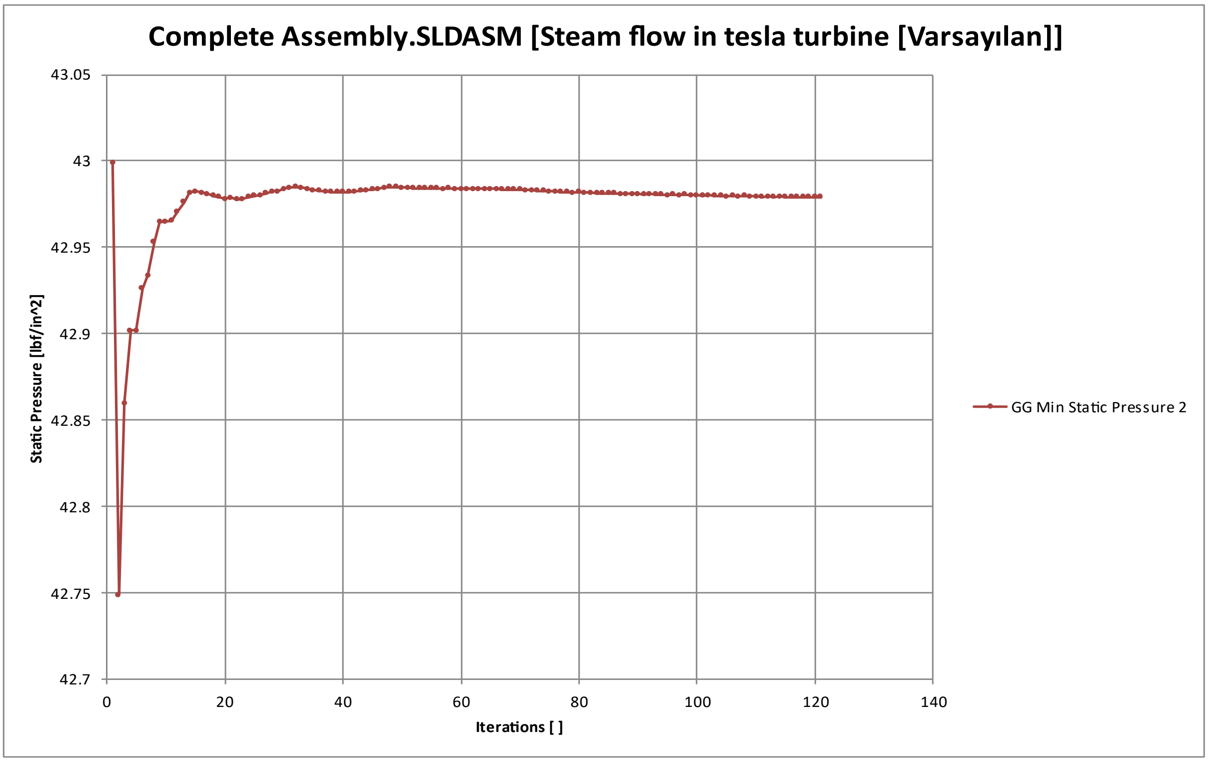

Figure 58: GG Minimum static Pressure 2 (No-load)

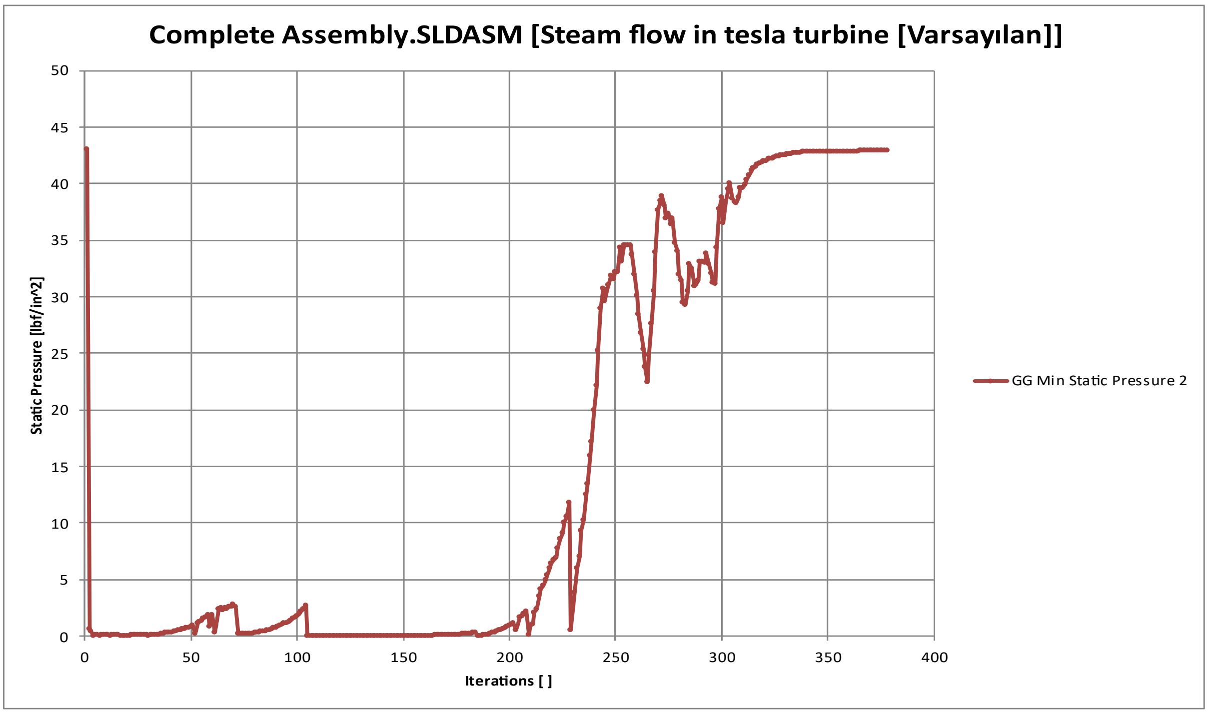

Figure 59: GG Minimum Static Pressure 2 (Full-load)

5.1.20 GG Minimum Temperature (Fluid) 1:

The final series of experiment/simulation is being presented. The first one to be noted is the temperature of the fluid. Certain things have remained same. This includes minimum temperature where it reaches at both no-load and full-load conditions.

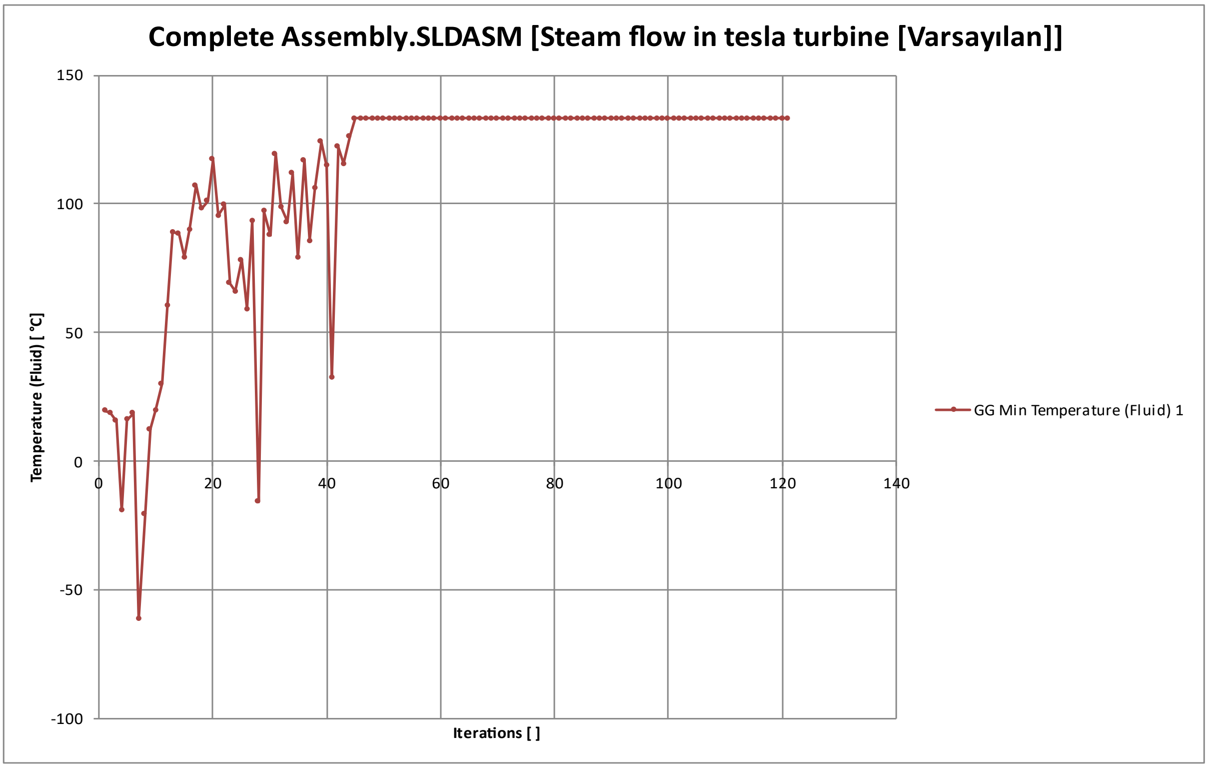

Figure 60: GG Minimum Temperature (Fluid) 1 (No-load)

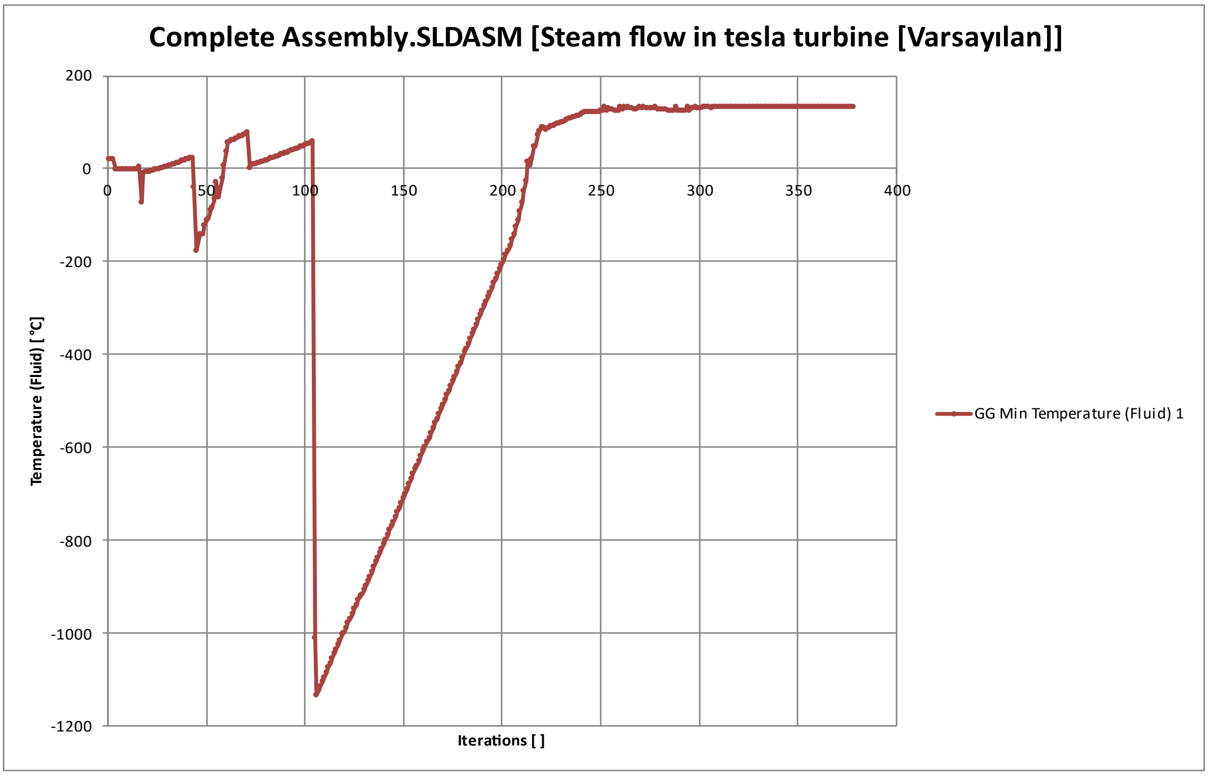

Figure 61: GG Minimum Temperature (Fluid) 1 (Full-load)

5.1.21 GG Minimum Dynamic Pressure 1:

As explained already, this doesn't change much in both the conditions. We have seen it in previous simulation results as well.

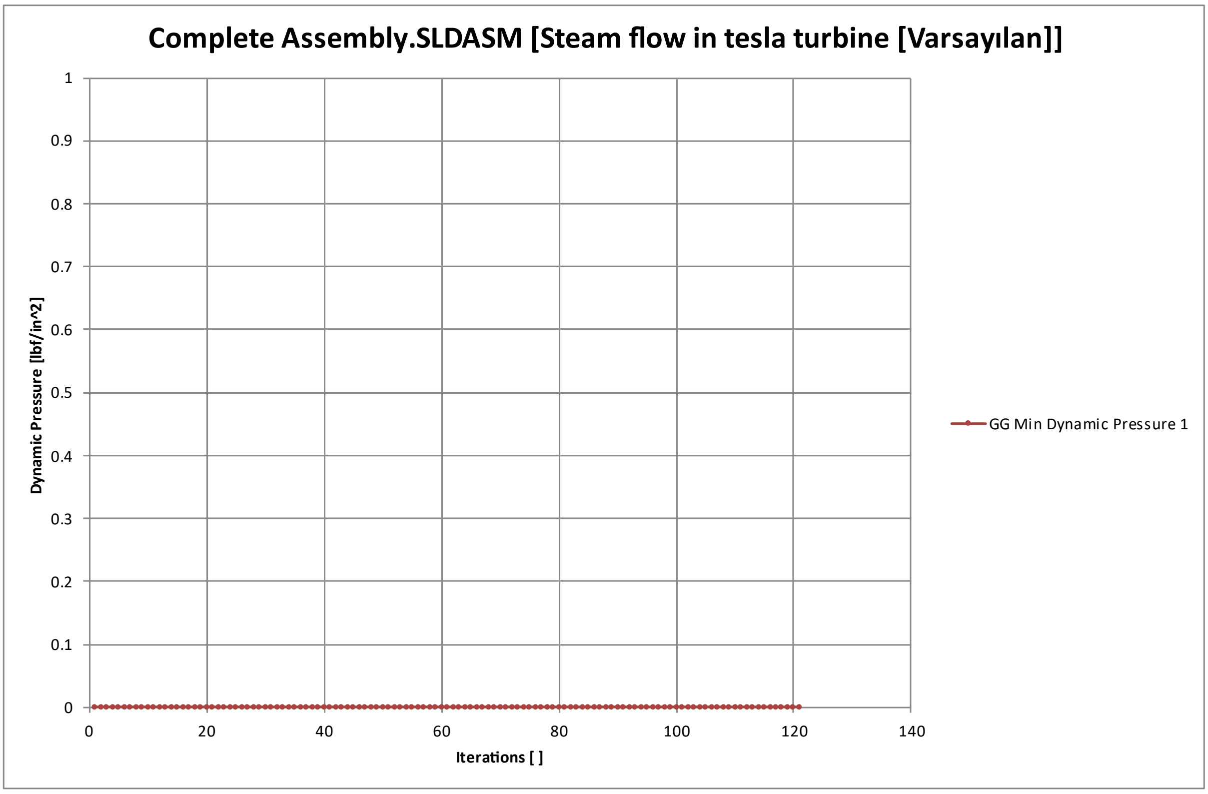

Figure 62: GG Minimum Dynamic Pressure (Fluid) 1 (No-load)

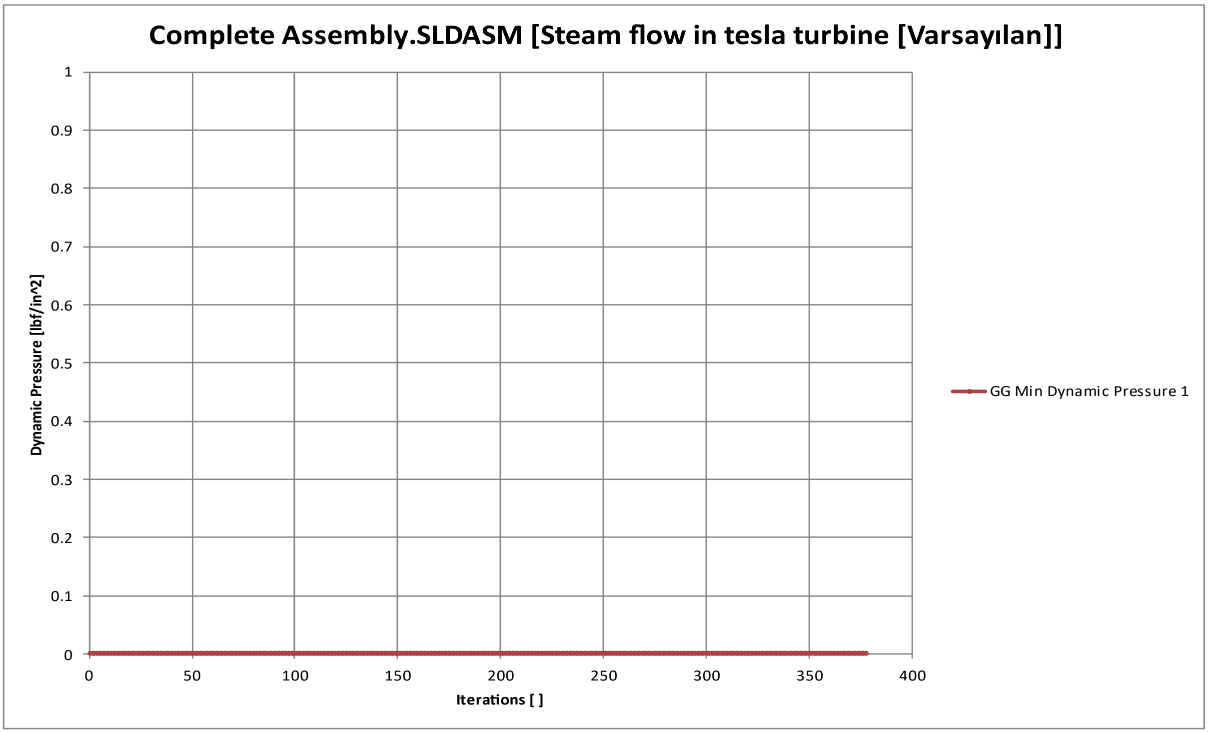

Figure 63: GG Minimum Dynamic Pressure (Fluid) 1 (Full-load)

5.1.22 GG Minimum Total Pressure 1:

Above discussion has clearly stated that this doesn’t change much either. That is why load has not much effect on this parameter as well. The only difference is the increased number of iterations.

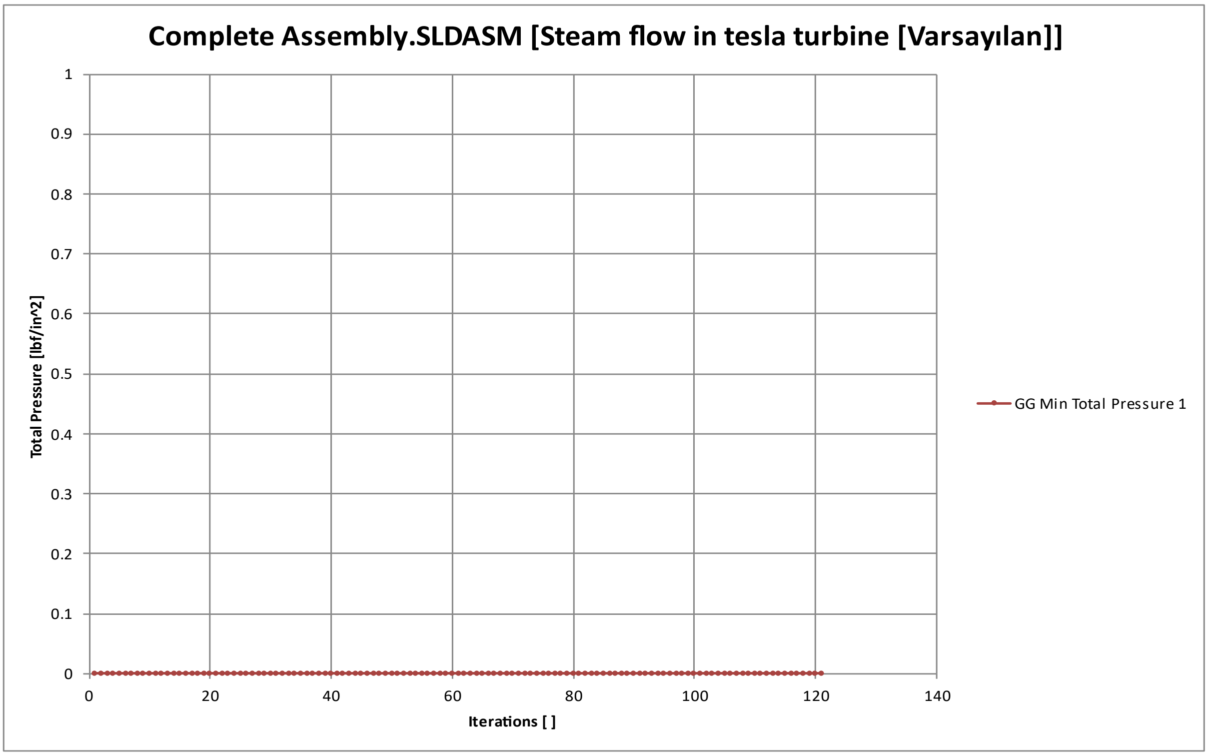

Figure 64: GG Minimum Total Pressure 1 (No-load)

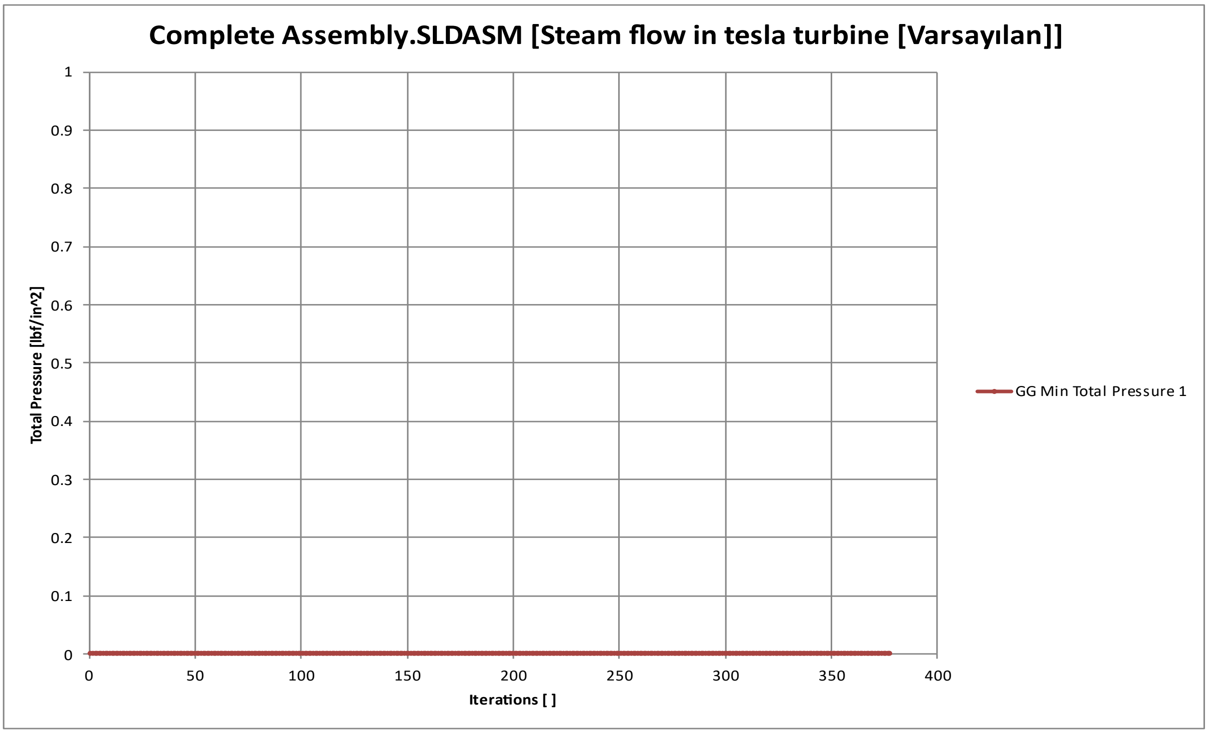

Figure 65: GG Minimum Total Pressure 1 (Full-load)

5.1.23 GG Minimum Static Pressure 1:

The only pressure that changes in both conditions. The only difference is the number of iterations and disruptions in the final result.

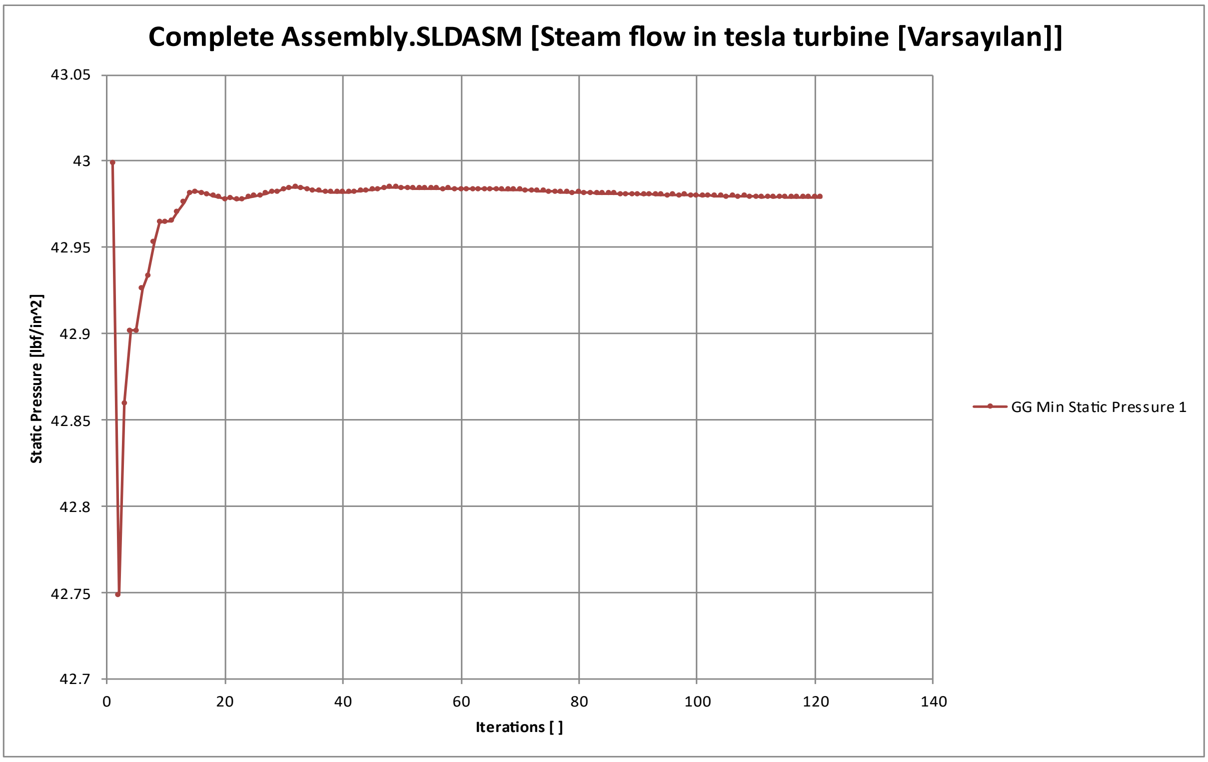

Figure 66: GG Minimum Static Pressure 1 (No-load)

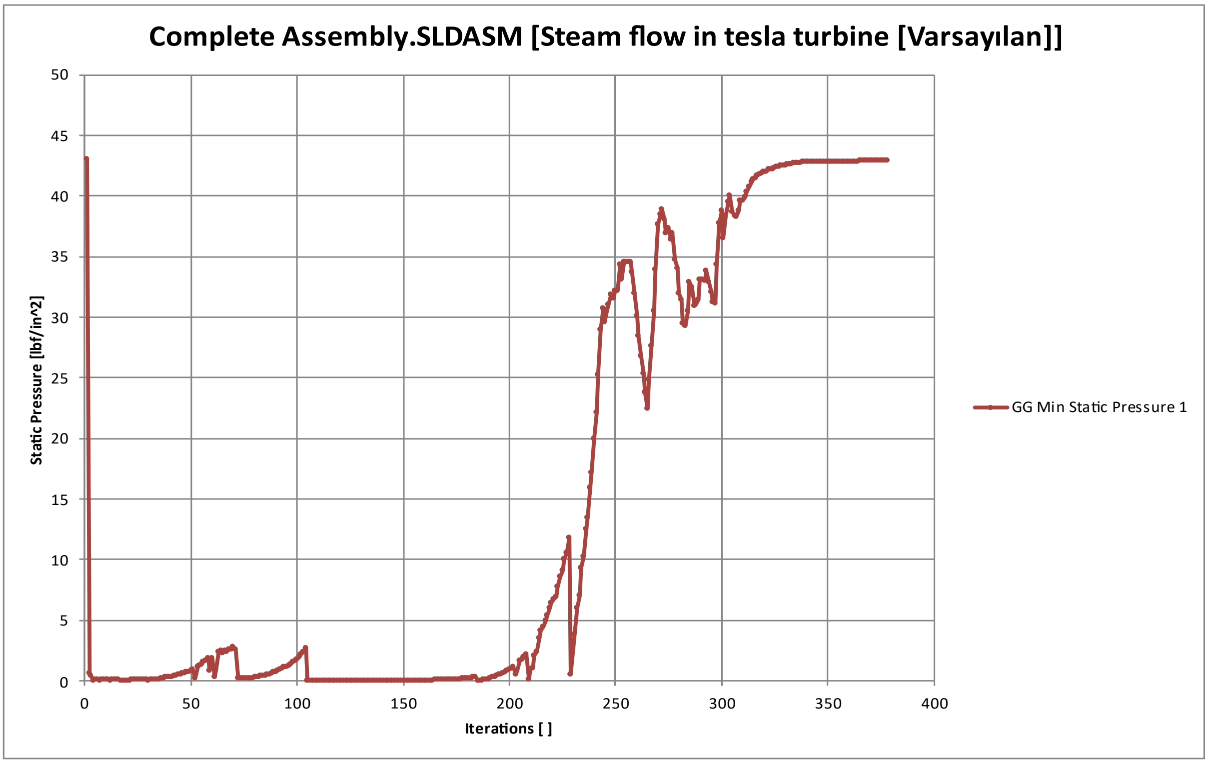

Figure 67: GG Minimum Static Pressure 1 (Full-load)

5.2 Comparison with Benchmark paper:

Turbine is the major component in this thesis. A benchmark paper [20] is established with which the results are compared. Tesla turbine has been developed in this paper. Performance of turbine was examined. Open water flow source is used as an input. The turbine's speed was examined with the help of tachometer.

The results have been evaluated using two power sources; the water flow in a rectangular weir and water flow in a hose using centrifugal pump.

5.2.1 The water flow in a rectangular weir:

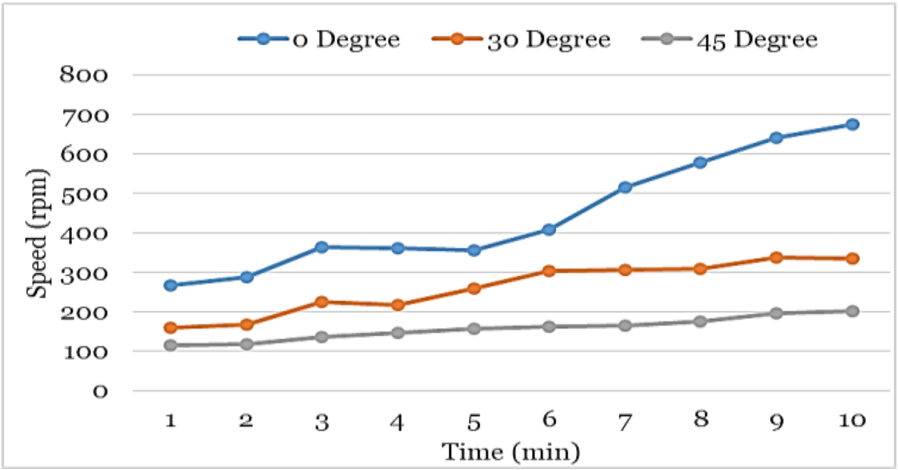

Figure 68: Speed and time relationship

The above graph depicts speed and time relationship at different degrees in the setup. It is observed that at 0 degree, the speed increases exponentially with time. At 30 and 45 degrees, the line gets linear as the time passes by.

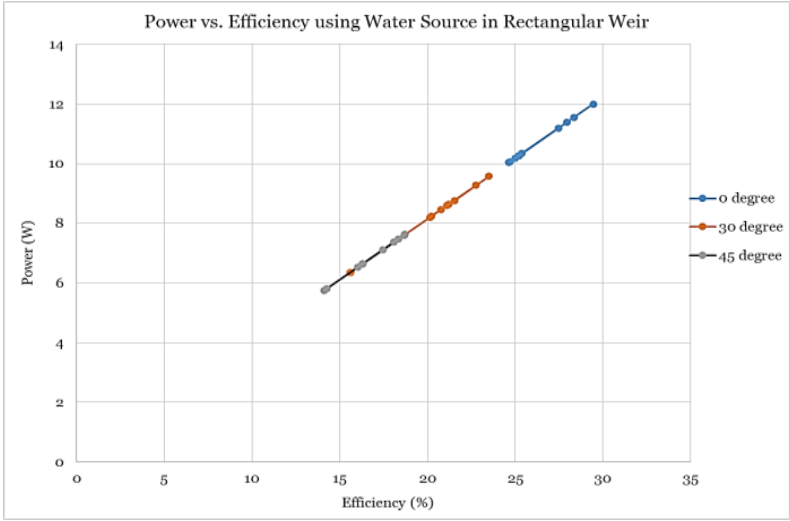

Figure 69: Power and efficiency relationship

The above figure depicts the power and efficiency relationship at three different angles. The angles are same as already discussed. The behavior is pretty linear but at 0 degrees the power is maximum.

5.2.2 Water flow in a hose using centrifugal pump:

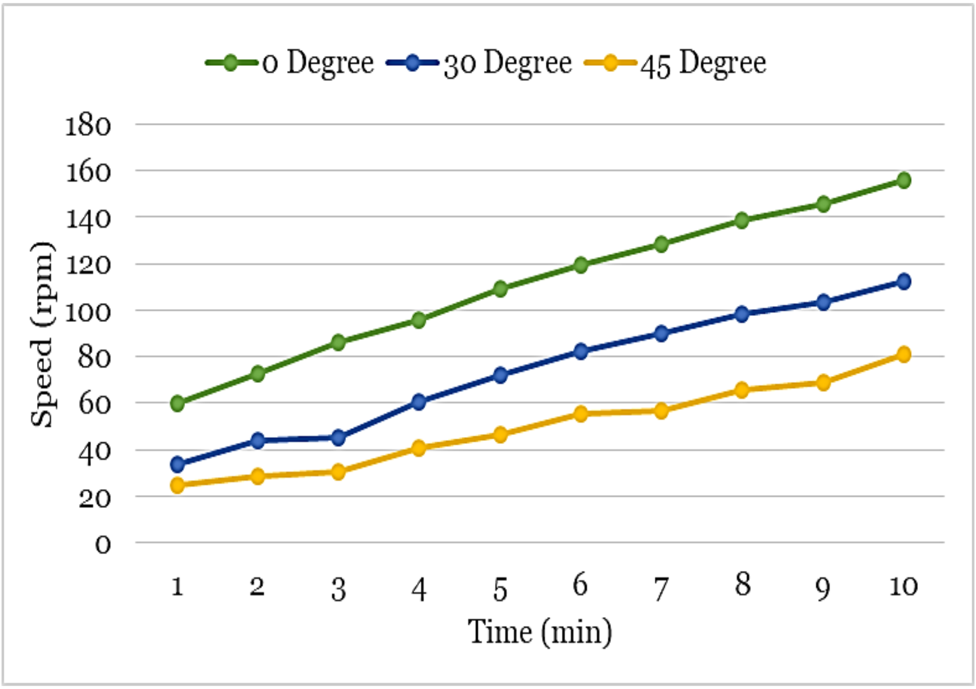

Figure 70: Speed and time relationship

The above figure shows relationship between speed and time. This experiment is also performed at 0, 30 and 45 degrees. As seen from the graph, speed is high at 0 degrees. The results try to get linear as the time passes by.

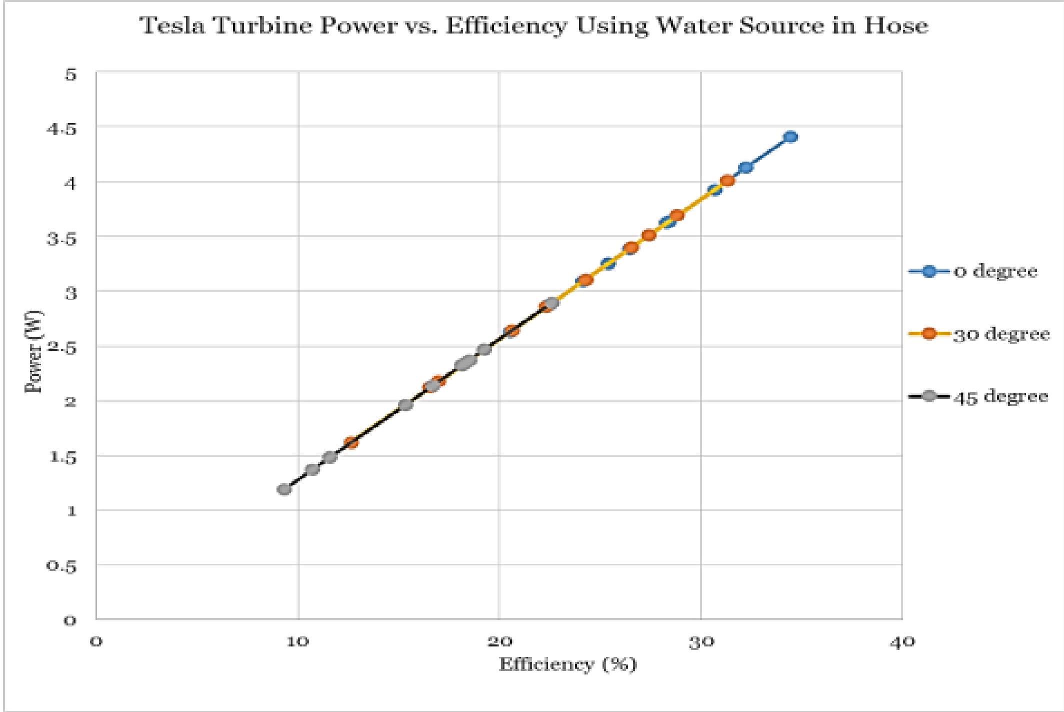

Figure 71: Power and efficiency relationship

The above graph depicts power and efficiency relationship. It is evident that at 0 degrees, the power is higher as compared to 30 and 45 degrees. The stepper it gets, the less efficient it becomes.

6 CHAPTER 6: “CONCLUSION AND RECOMMENDATIONS”

This research was carried out to build a system that uses domestic geyser as a main part to harvest energy. This energy generation or harvesting technique is relatively new in power generation. This thesis is a Simulation-based work. No actual hardware is prepared. SolidWorks is used for Simulation generations.

Starting from just a domestic geyser, a geyser with certain qualities was developed. The geyser is used to generate the steam. Moving on, the steam is used to rotate the turbine which is coupled with a generator. Turbine is the major part of this Simulation-based model. The turbine model is based on the Tesla Turbine. Tesla turbine is basically a bladeless turbine that generate energy using the centripetal force. Since it is a bladeless turbine and uses disk as an alternative, its cost is relatively low as compared to others. Another main advantage of using this concept is that this kind of turbine can work with any kind of fluid unlike conventional turbines that only use a single kind of fluid.

It was concluded that temperature was the most affected parameter as the iterations kept on increasing. Minimum values different parameters for solid and fluids were found that helped in understanding the system much better. A detailed summary has already been described in the “Result and Discussion” chapter. The system worked well enough which was capable of harvesting energy efficiently than other methods being used to harvest energy. Calculations were performed to find the Revolutions per Minute as well. Operating points were found with the help of literature survey and Hit-and-Trial method.

The system was designed in such a way that high pressured steam is produced from the geyser and which eventually rotates the turbine rotor. As a result, electric power is produced that could be stored in the battery afterwards. The outlet orifice of the turbine is connected back to the water entry pipe assembled to the geyser. As the end point is connected to the generator, it produces electric charge. Due to back-and-forth connections, the system is industrial friendly which means it would produce less pollution.

In future, the designing of an actual hardware could be very helpful with the study of this Simulation-based model developed in this thesis. It would save a lot of time in building an actual one because the selection of material would be quite easy. The selection of turbine could be done very efficiently. Domestic geyser would help in reducing the cost and it would benefit the end-consumer. The goal was to develop a system that helps the common man and this thesis has achieved that idea sufficiently and efficiently.

For future works, the design of the whole system could be improved with one cause in mind i.e., increased efficiency. This could be in terms of cost, quantity of energy produced and quantity of energy preserved and utilized. One way of doing it is using bio-fuel instead of regular gas. This would be eco-friendlier and more cost effective. Another thing which can be added to this system is the steam arrestor. This would stop and steam hammering going on in the system. The number of discs could be increased and instead of using simple discs, horizontal screwed discs could be used that would make the steam more reliable and efficient.

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7 Appendix:

7.1 Assembly:

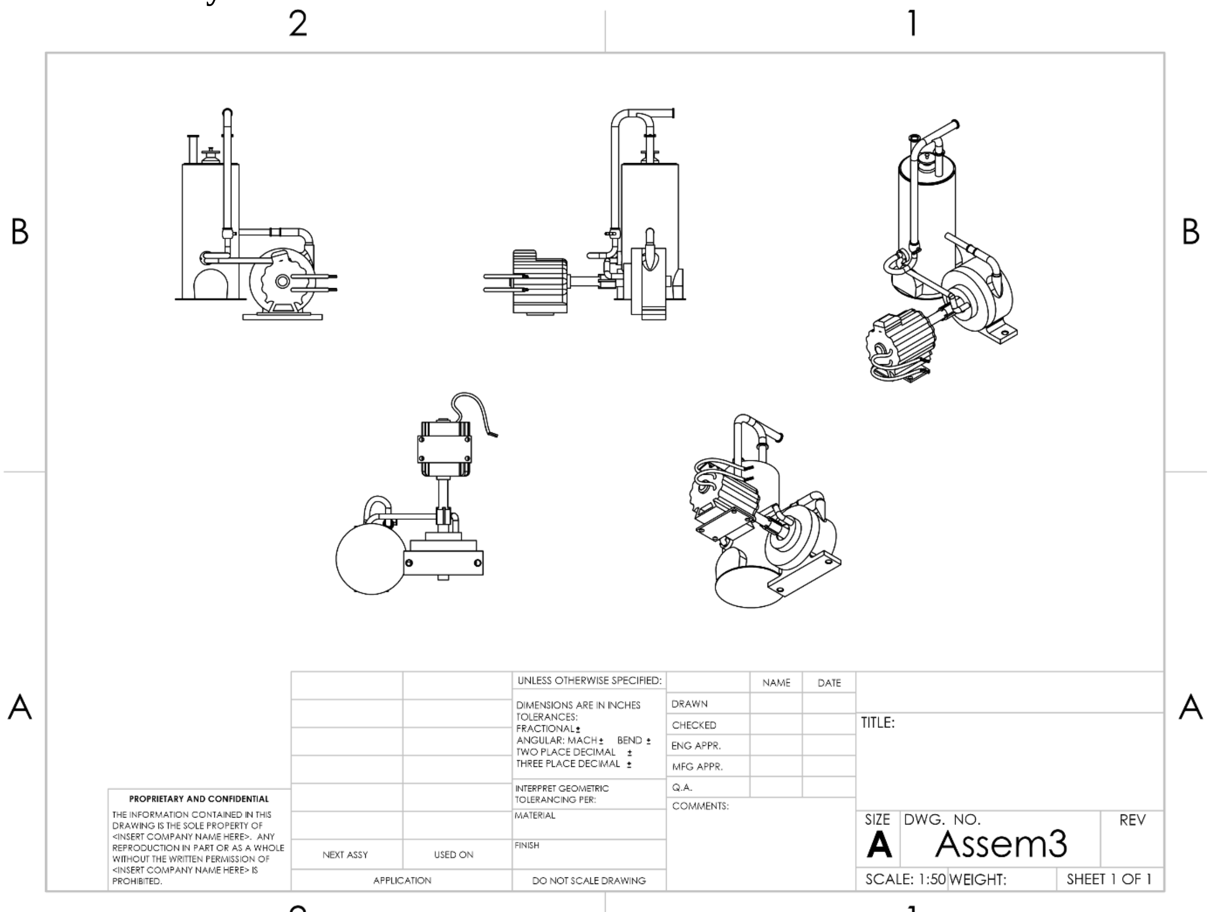

Figure 72: Complete system assembly

7.2 Turbine Design:

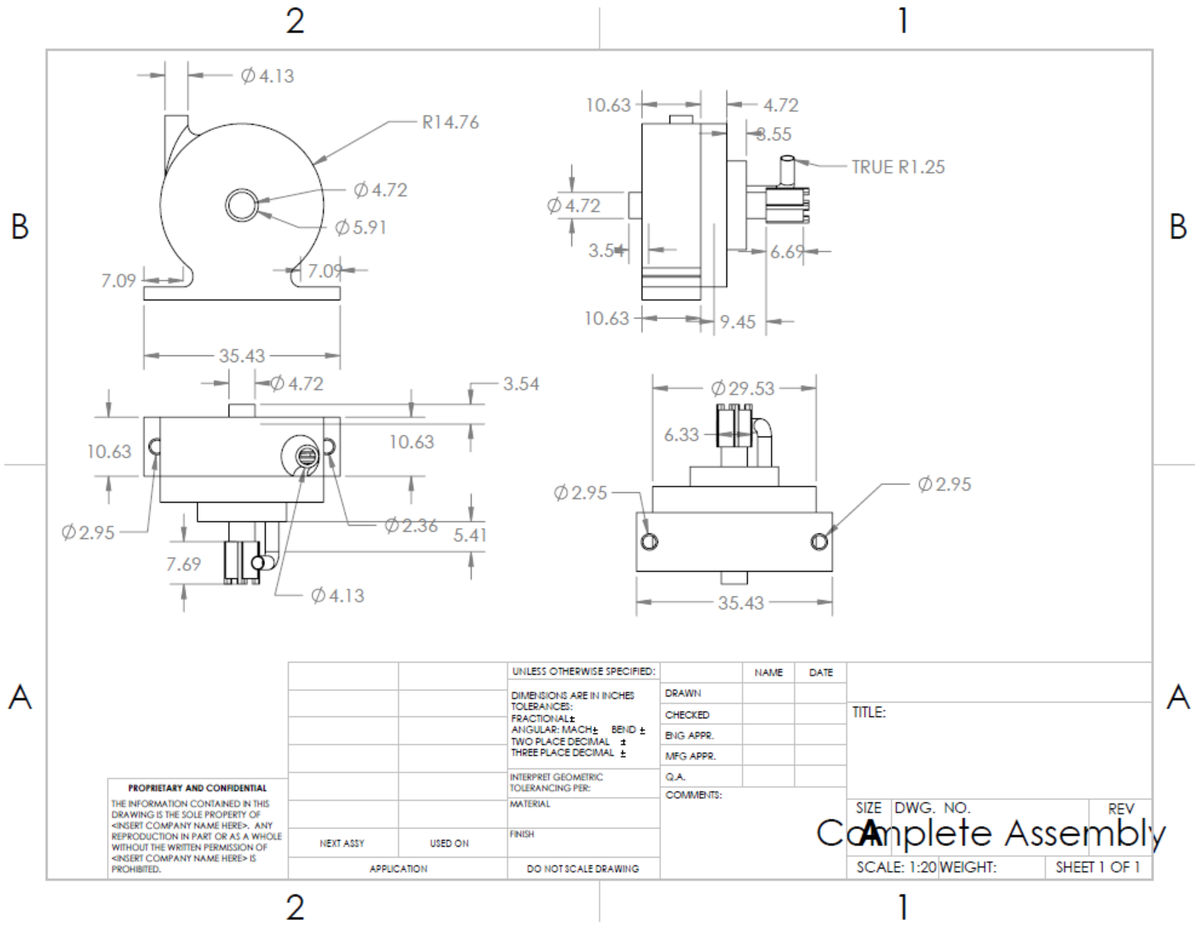

Figure 73: Complete Turbine assembly

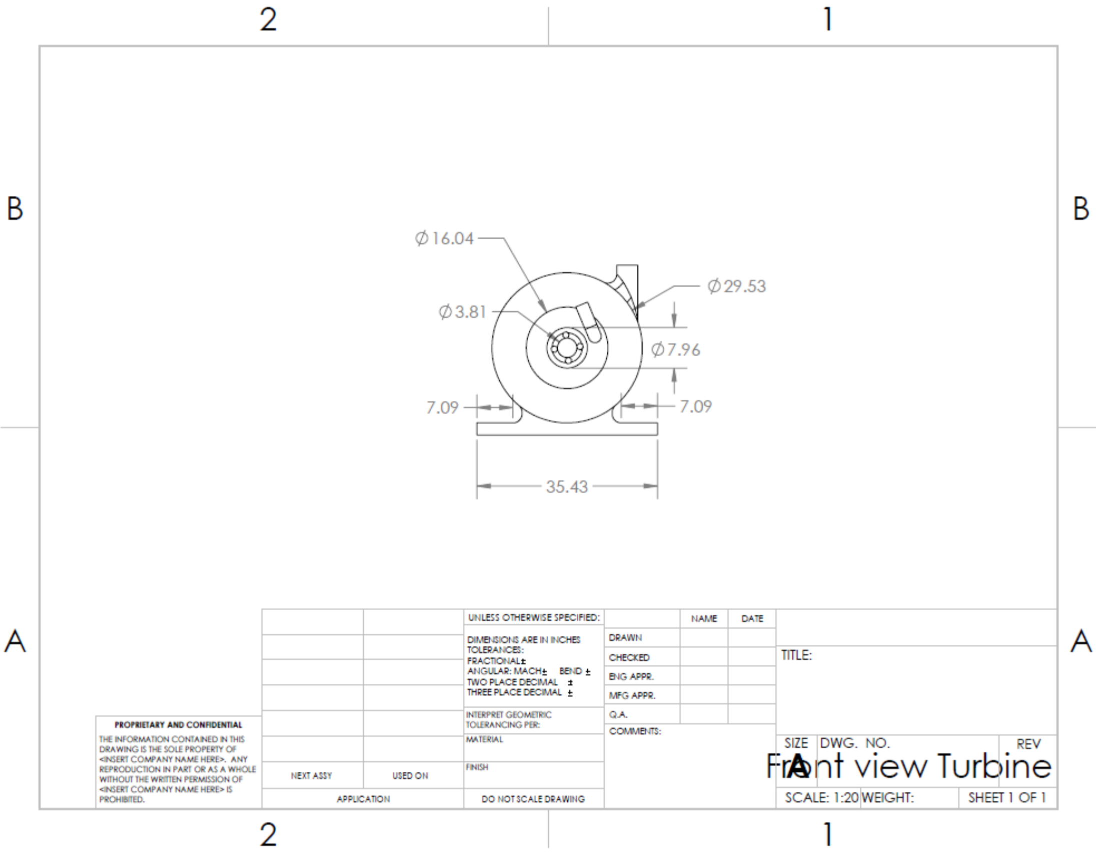

Figure 74: Turbine’s front view

Taqi Haider

by Farhan Hassan

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