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Theme

**Study and Design of a Biomass Pyrolysis Machine for
Hydrogen Production**

Presented by: OUADAH TSABET Souad

Led by:

Pr: HOCINE Abdelkader

Dr: HABBAR Ghania

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THANKS

To God, the One and Only God, and May God's blessings and peace be upon the Seal of the Prophets, Muhammad, and upon all his family and companions.

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DEDICATION

In the name of God, the most gracious, the most merciful. Praise be to God that His grace is righteous. There is nothing left for others to offer me. My father did everything to be my support and my safe haven. My constant support and encourager. When they call me by his name, I feel happy and proud. That I am his daughter. And its fruit. Whoever sees the reflection of my success and joy with a sparkle in his eyes. I cannot say thank you, for it is only said at the end, and I always see myself at the beginning... To the one who makes himself a burning candle that lights the path to success for us, I ask God to provide us with At your age to see the fruits you have come to reap, here is the beating of my rational, congratulatory heart. If joy brings you... start it with your mother.

We have the love of my mother, whose prayers and contentment were mine during the journey. May God protect and take care of you, my dear. God bless you.

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CO ₂	Carbon dioxide	5
H ₂	Hydrogen	6
CO	Carbon monoxide	6
CH ₄	methane	6
C	Carbon	23
H	humidity	23
O	Oxygen	23
N	Nitrogen	23
S	Sulphur	23
FC	Constraint function	33
FP	Main function	33
DAST	Design and Analysis System Technique	34
FAST	Function Analysis System Technique	34
CAO	Computer aided design	39
PSA	pressure swing adsorption	41

ABSTRACT

This study and design of a biomass Pyrolysis machine for efficient hydrogen production is the subject of the present master project. Pyrolysis procedure is a high-temperature decomposition process without oxygen, converts biomass into hydrogen gas. It is characterized by some key parameters like temperature, heating rate, and feedstock type are optimized for maximum yield and efficiency.

Through this first contribution, an attention is focused firstly on the design of Pyrolysis machine elements under SOLIDWORK Software, than numerical simulation is developed for the heating process of biomass.

This study supports sustainable hydrogen production from biomass, addressing technical, environmental, and economic goals for a low-carbon energy future.

RESUME

L'étude et la conception d'une machine de pyrolyse de la biomasse pour une production efficace d'hydrogène est le sujet du présent projet de master. La procédure de pyrolyse est un processus de décomposition à haute température sans oxygène, qui convertit la biomasse en hydrogène gazeux. Elle est caractérisée par certains paramètres clés tels que la température, la vitesse de chauffage et le type de matière première, qui sont optimisés pour obtenir un rendement et une efficacité maximums.

Dans cette première contribution, l'attention est d'abord portée sur la conception des éléments de la machine de pyrolyse sous le logiciel SOLIDWORK, puis une simulation numérique est développée pour le processus de chauffage de la biomasse.

Cette étude soutient la production durable d'hydrogène à partir de la biomasse, en répondant aux objectifs techniques, environnementaux et économiques d'un avenir énergétique à faible teneur en carbone.

المخلص

هذه الدراسة والتصميم لآلة التحلل الحراري للكتلة الحيوية لإنتاج الهيدروجين بكفاءة هو موضوع المشروع الرئيسي الحالي. إجراء الانحلال الحراري هو عملية تحلل حراري بدرجة حرارة عالية بدون أكسجين، يحول الكتلة الحيوية إلى غاز الهيدروجين. وتتميز ببعض المعلمات الرئيسية مثل درجة الحرارة، ومعدل التسخين ونوع المادة الأولية التي يتم تحسينها لتحقيق أقصى قدر من الإنتاجية والكفاءة.

من خلال هذه المساهمة الأولى، ينصب الاهتمام أولاً على تصميم عناصر آلة التحلل الحراري في إطار، ثم يتم برنامج SOLID WORK تطوير محاكاة عددية لعملية تسخين الكتلة الحيوية

وتدعم هذه الدراسة الإنتاج المستدام للهيدروجين من الكتلة الحيوية، وتتناول الأهداف التقنية والبيئية والاقتصادية لمستقبل طاقة منخفضة الكربون

A decorative border resembling a scroll, with a vertical strip on the left and rounded corners on the right, framing the text.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Pollution is the introduction of harmful substances or products into the environment, resulting in adverse effects on natural ecosystems and human health. It can take the form of air, water, soil, or noise pollution, caused by various human activities such as industrial processes, vehicle emissions, waste disposal, and the use of chemicals. [1]

Hydrogen production from electrolysis involves splitting water into hydrogen and oxygen using an electrical current. This process requires an electrolyser, which can operate using various types of technology such as alkaline, proton exchange membrane, or solid oxide electrolysers. [2]

Gasification is a process that converts organic or fossil fuel-based carbonaceous materials into hydrogen, carbon monoxide, and carbon dioxide. This is achieved by reacting the material at high temperatures (typically above 700°C), without combustion, with a controlled amount of oxygen and/or steam. [3]

The growing concern over environmental sustainability and the need for alternative energy sources have directed significant attention towards biomass as a renewable resource. Biomass pyrolysis, a thermochemical process that converts organic materials into valuable products such as bio-oil, biochar, and gases, offers a promising pathway for hydrogen production. Hydrogen, a clean and highly efficient energy carrier, plays a crucial role in the transition to renewable energy systems. [4]

This study focuses on the design and development of a biomass pyrolysis machine specifically tailored for efficient hydrogen production. The process involves the thermal decomposition of biomass in an oxygen-limited environment, which results in the breakdown of organic materials and the release of syngas—a mixture of hydrogen, carbon monoxide, and other gases. Optimizing the pyrolysis process parameters is essential to maximize hydrogen yield and improve the overall efficiency of the system. [5]

This master project is divided into four chapters, the first one presents an overview of general hydrogen production and pyrolysis systems, focusing on the process of converting biomass into valuable products.

The chapter begins with a description of biomass types, characteristics and availability, then moves on to the fundamentals of hydrogen production, with a focus on pyrolysis.

The chapter explains the principles of pyrolysis, the types of pyrolysis processes and the products obtained, including bio-oil, syngas and biochar.

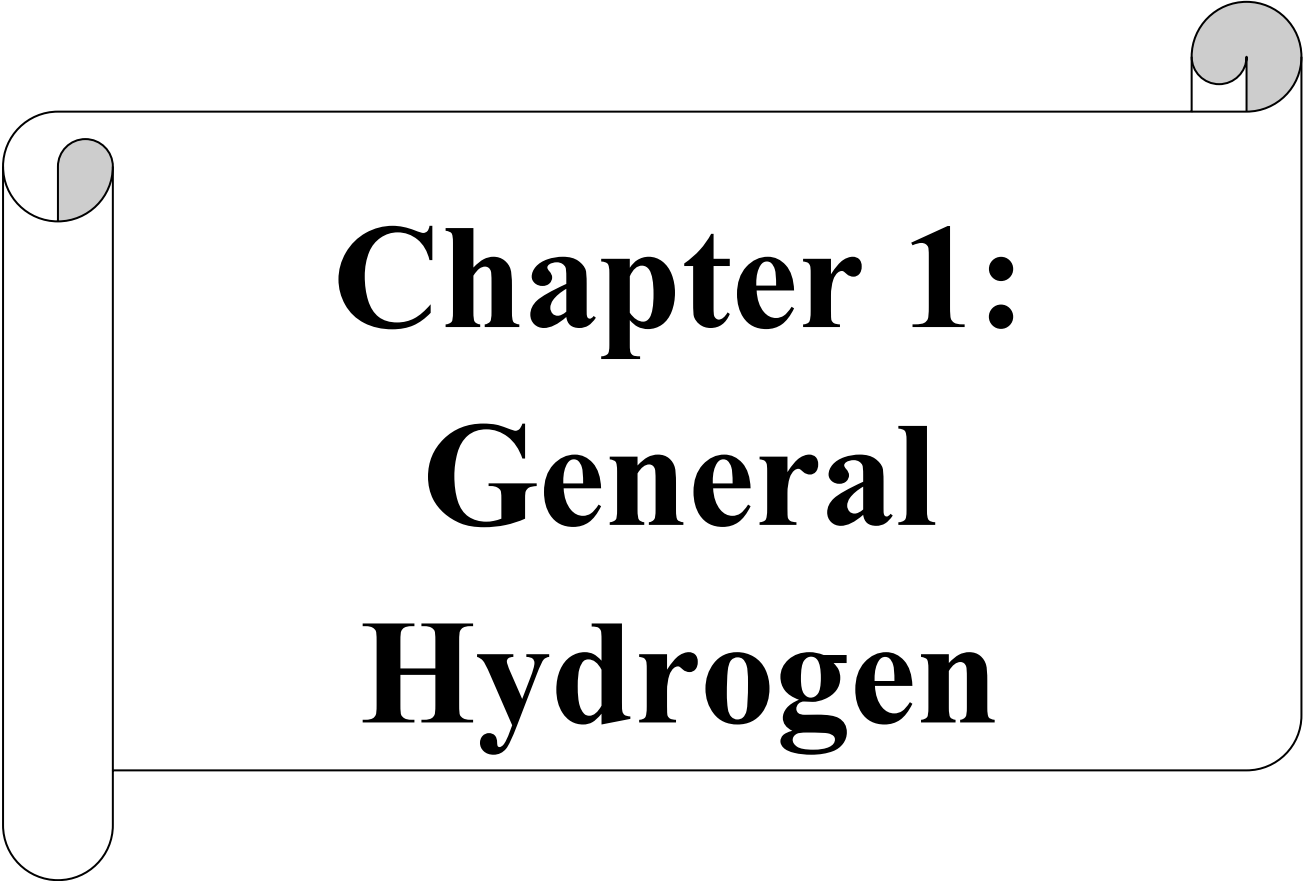
GENERAL INTRODUCTION

The chapter two is describes the basic components of a hydrogen pyrolysis machine.

The chapter three is focuses on the design considerations and technical aspects of a pyrolysis machine for hydrogen production.

Chapter four presents the numerical simulation of the pyrolysis process using ANSYS software. This chapter explains the study of heat transfer in the reactor.

The results of the ANSYS simulation provide insights into the optimization of the pyrolysis process, enabling the design to be optimized and the efficiency of hydrogen production to be improved.



Chapter 1: General Hydrogen

1.1. Hydrogen Definition

Hydrogen is a chemical element that is denoted by the symbol H and has an atomic number of 1. It is the lightest and most abundant element in the periodic table. Hydrogen is a colourless, odourless, and highly flammable gas in its pure form. It is the primary building block of the universe and plays a fundamental role in various chemical reactions and physical processes [6].

Hydrogen is the simplest and lightest element, consisting of a single proton and a single electron. It belongs to a group of elements called the alkali metals, but it is often placed separately due to its unique properties. Hydrogen has three isotopes: protium, deuterium, and tritium, with protium being the most common and abundant.

Hydrogen is rarely found in its elemental form on Earth because it readily combines with other elements. It is commonly found in compounds such as water (H₂O), hydrocarbons, and organic molecules. Water, in particular, consists of two hydrogen atoms bonded to one oxygen atom and is essential for sustaining life on Earth.

Hydrogen has numerous applications in industry, including its use in the production of ammonia for fertilizers, petroleum refining, and as a reducing agent in various chemical processes. It is also used as a fuel in rockets and can be burned in internal combustion engines [7].

In recent years, hydrogen has gained significant attention as a potential clean and sustainable energy carrier. When combined with oxygen in a fuel cell, hydrogen can produce electricity with water as the only by product. This makes hydrogen fuel cells a promising alternative to traditional combustion engines, offering the potential for reduced greenhouse gas emissions and improved air quality [8].

Hydrogen can be produced from various sources, including fossil fuels, biomass, and renewable energy sources such as solar and wind power. The method of production can determine the environmental impact and sustainability of hydrogen, with efforts focused on developing technologies for producing "green hydrogen" using renewable energy sources.

Overall, hydrogen is a versatile element with diverse applications in industry, energy, and scientific research. As the world seeks cleaner and more sustainable alternatives to traditional

fuels, hydrogen is expected to play a crucial role in the transition to a low-carbon economy [9].

1.2. Hydrogen chain

The hydrogen chain refers to the entire process of producing, transporting, storing, and distributing hydrogen. It involves several interconnected steps that ensure the availability and accessibility of hydrogen as an energy resource.

1.2.1. Production methods

Hydrogen can be produced through different methods, each with its own advantages and challenges. Some of the commonly used production methods include [10]:

- **Steam Methane Reforming (SMR):** This method involves reacting natural gas with steam to produce hydrogen and carbon dioxide as shown in Figure 1.1.

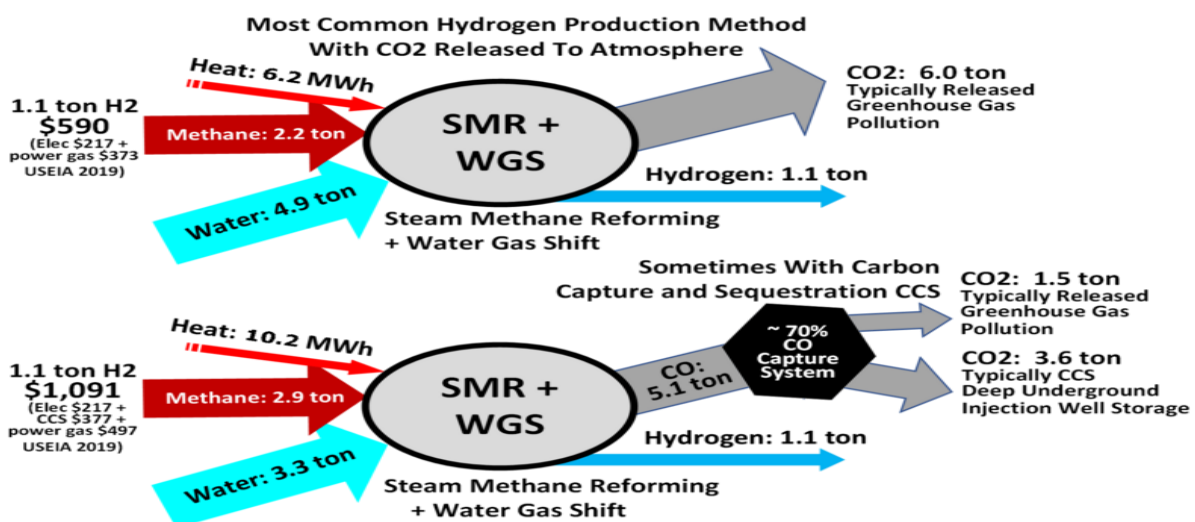


Figure 1.1. Illustrating inputs and outputs of steam reforming of natural gas, a process to produce hydrogen and CO₂ greenhouse gas that may be captured with CCS [11].

- **Electrolysis:** In this process, an electric current is passed through water to split it into hydrogen and oxygen. Figure 1.2 Electrolysis can be powered by renewable energy sources, making it a sustainable production method [12].

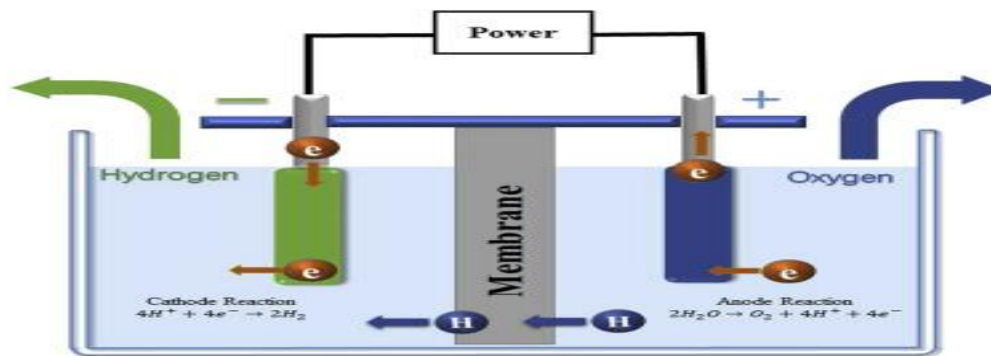


Figure 1.2. Water electrolysis technology [12].

- **Biomass Gasification:** Biomass, such as agricultural waste or energy crops, can be converted into hydrogen through a process called gasification as shown in Figure 1.3. This method is considered renewable and helps reduce greenhouse gas emissions.

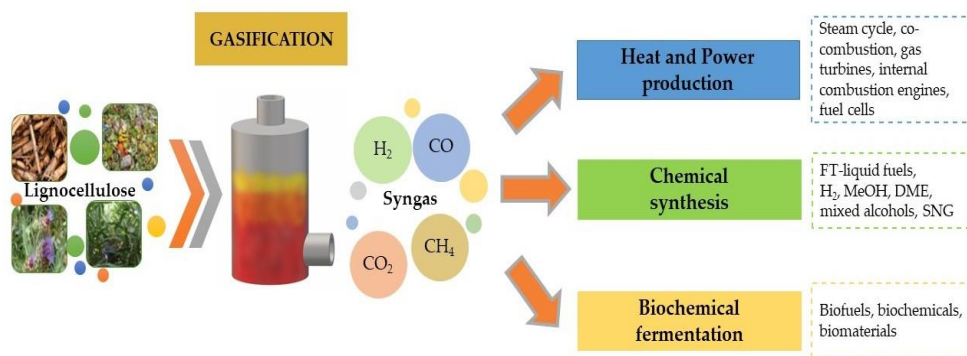


Figure 1.3. Schematic representation of biomass gasification process and syngas final use [13].

1.2.2. Transportation

Transporting hydrogen efficiently and safely is a critical aspect of the hydrogen chain. Hydrogen has unique properties that pose challenges for its transportation. It has low energy density, requiring specialized storage and transport solutions [14].

One option for hydrogen transport is through pipelines, similar to natural gas pipelines. However, hydrogen has different physical properties, and modifications to existing infrastructure may be necessary to ensure its safe and efficient transportation. Another method is to transport hydrogen as compressed gas or liquefied hydrogen. Compressed hydrogen is stored at high pressures, while liquefied hydrogen is cooled to very low temperatures. Figure 1.4, both methods require dedicated infrastructure and careful handling to prevent leaks or accidents [15].

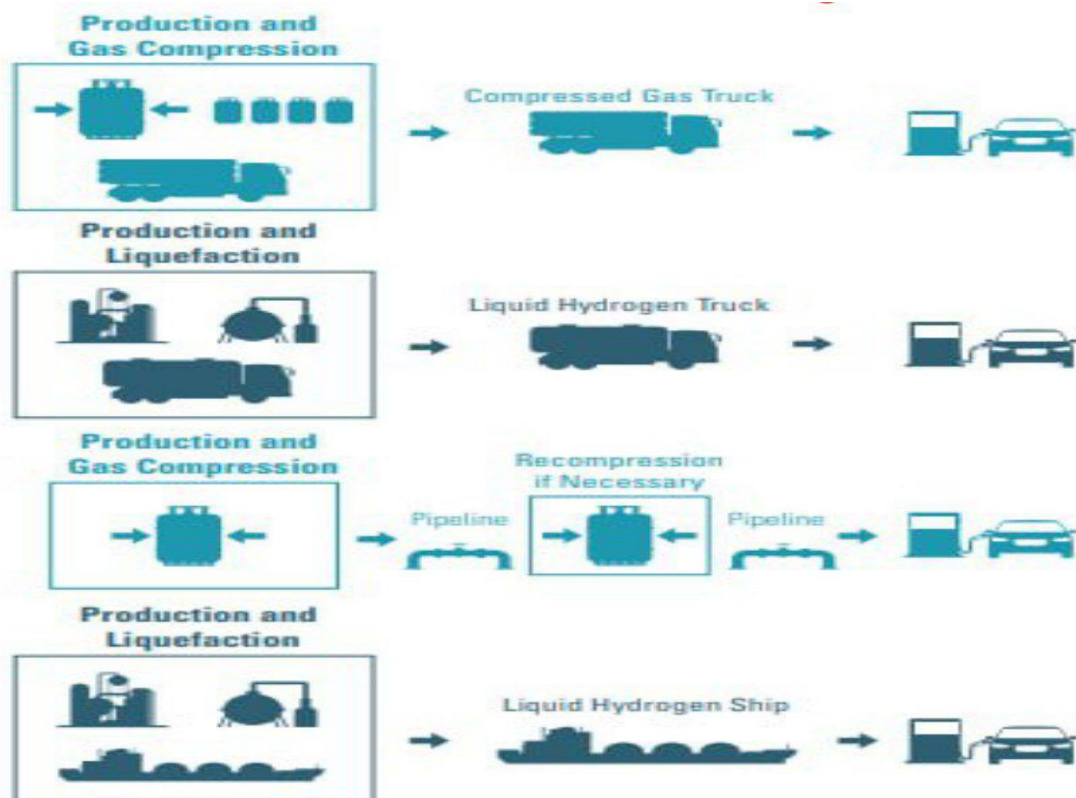


Figure 1.4. Primary Means of Hydrogen Transportation [15].

Additionally, advancements are being made in the development of solid-state hydrogen carriers, which could potentially offer a more compact and efficient means of hydrogen transport. These carriers involve materials capable of safely storing and releasing hydrogen, providing a promising alternative to conventional storage and transportation methods.

The choice of transport method depends on factors such as the distance of transportation, available infrastructure, safety considerations, and economic feasibility.

1.2.3. Storage

Efficient storage of hydrogen is essential for its integration into energy systems. Hydrogen can be stored using various technologies, each with its own advantages and challenges.

Compressed gas storage involves storing hydrogen in high-pressure tanks. The tanks must be designed to handle the high pressures and ensure the safe containment of the gas. Compressed gas storage is suitable for stationary applications and some mobile applications where weight and space requirements allow for the use of high-pressure storage vessels.

Another storage method is liquid hydrogen storage, which involves cooling hydrogen to very low temperatures to keep it in a liquid state. Liquid hydrogen offers a higher energy density compared to compressed gas storage, enabling more hydrogen to be stored in a given space.

However, it requires specialized infrastructure and insulation to prevent evaporation and ensure safe handling. Solid-state storage technologies are also being explored to address the challenges of hydrogen storage. These technologies involve using materials, such as metal hydrides or complex chemical compounds that can absorb and release hydrogen. Solid-state storage offers the potential for safe and compact hydrogen storage, but further research and development are needed to improve storage capacity and efficiency.

The choice of storage technology depends on factors such as space requirements, energy density, safety considerations, and the specific application or end-use of the stored hydrogen [16].

1.2.3.1. Gas storage and distribution

1.2.3.1.1. Storage

The disadvantage of this storage method is its bulk - only 14 kg/m³ at 20 MPa and ordinary temperature, compared with 100 kg/m³ for methane - and above all its weight, which results from the use of low-stress steels to avoid problems of hydrogen embrittlement.

What's more, this pressure level corresponds to an optimum - in terms of mass - linked to hydrogen's compressibility characteristics.

Note that the energy required to compress hydrogen from ambient pressure to a pressure of 20 MPa is of the order of 7% of the energy contained in the hydrogen.

Stationary storage to enable vehicles to fill their tanks quickly at the pump - less than 5 minutes for a light vehicle and certainly not half an hour for a heavy goods vehicle - filling stations will need to have much larger storage units, working at much higher pressure, especially taking into account heavy goods vehicle requirements. Figure 1.5

Local reinforcements are placed during the winding process, in particular at the level of the base plates, but also at the level of the clamps holding these tanks in place.

In addition, it does not particularly appreciate humidity, and the resin, chosen for its mechanical qualities or adhesion to the fiber, does not necessarily provide sufficient protection, especially for very long service lives and numerous pressurization cycles.

They can also have an impact on the future of the high-pressure sector compared with the 20K liquid hydrogen sector. Having an International Standard that specifies the rules to be respected for the design, manufacture, testing and use of high-pressure hydrogen tanks, as well as liquid hydrogen tanks, can only encourage the development of the hydrogen sector by clarifying the rules of the game for everyone involved [17].

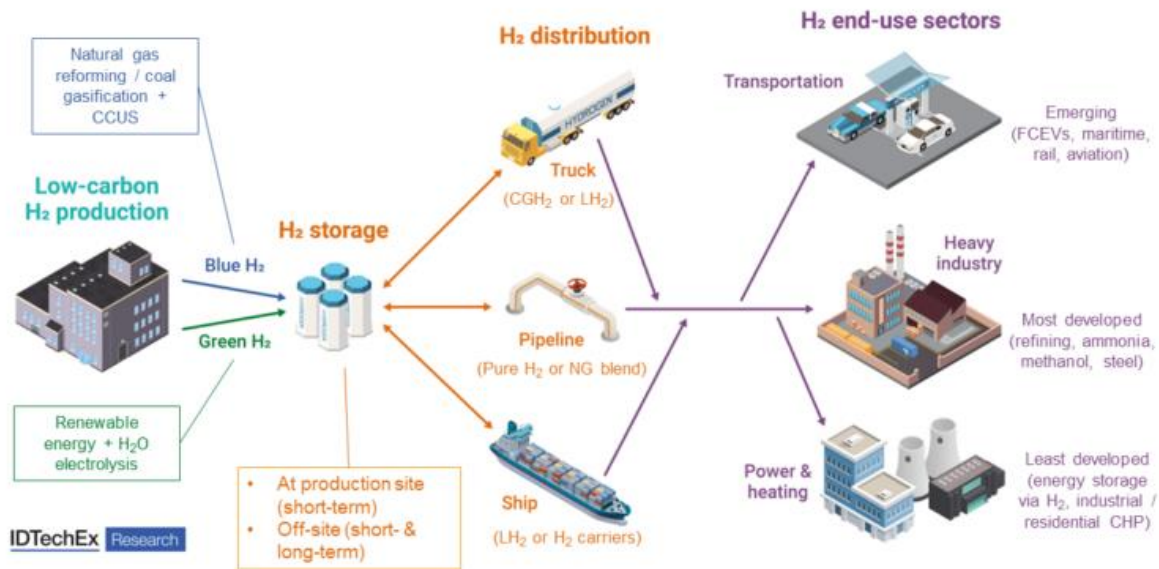


Figure 1.5. Storage and distribution is vital part of hydrogen value chain [18].

1.2.3.1.2. Transport and distribution

Although less favorable in terms of the quantity of hydrogen stored per unit volume, compressed-gas hydrogen storage is a widespread and relatively easy-to-implement technology.

Western Europe has the largest pipeline network, some 1,500 km compared with 900 km in the USA. The main European countries using hydrogen pipeline networks are France, Germany and Benelux.

Depending on the distribution strategy in place, as described below, hydrogen would be transported either directly into the tanks used to fill users' tanks, or into users' replacement tanks. There are two possibilities for filling a reservoir: - direct transfer using a compressor, but the compressor requires a minimum of continuity and stability in its operating conditions, particularly in terms of flow rate: a situation that is hardly compatible with the numerous successive fillings carried out in a distribution station, - transfer from an overpressure reserve.

In fact, it is the superposition of these two operations that is most suitable: the hydrogen in the reserve is maintained at a constant pressure of 5 MPa above the filling pressure, thanks to a compressor controlled by an automatic pressure regulator. This is less the case for large transport vehicles or buses, which are easier to equip with large tanks and for which a longer filling time is more acceptable.

Storage by adsorption of compressed hydrogen by carbon structures would have the advantage of lowering the pressure in the tank for the same quantity stored [18].

1.2.3.2. Liquid storage and distribution

1.2.3.2.1. Storage and distribution

While the density of gaseous hydrogen at atmospheric pressure and 20°C is 0.084kg/m³, and 14.9kg/m³ for compressed hydrogen at 22Mpa and 20°C in commercial gas tubes, it is 70.9kg/m³ in the liquid state.

In its liquid state, hydrogen is almost 800 times denser than gas, making it an obvious choice for storage and transport, but a certain level of cryogenic technology is required, whether to liquefy it or keep it in its liquid state.

Some of this cold hydrogen is used to help lower the system temperature: in other words, the hydrogen is partly its own refrigerant. The transition from one hydrogen state to the other is reversible; it is exothermic in the ortho-para direction and endothermic in the para-ortho direction.

The efficiency of a liquefier, the Carnot efficiency, is the ratio of the theoretical energy W_{th} to the actual energy W_r required to liquefy the hydrogen: $= W_{th} / W_r$ The liquefaction energy W_{th} is of the order of 3.9kWh/kgH₂ for hydrogen gas initially taken at an atmospheric pressure of 0.1MPa.

Typical tank architecture Like all low-temperature, cryogenic liquids, liquid hydrogen is stored in "cryostats", double-insulated containers designed to limit unavoidable heat input.

The first barrier is thermal insulation against direct heat conduction, provided by the vacuum maintained in the cryostat's double wall [17].

1.2.3.2.2. Transport and distribution

This same technology is due to be applied by the new GM/BMW consortium. From the point of view of transport to distribution points, liquid hydrogen is commonly transported by truck to supply industrial customers.

These vehicles can carry up to 3.5t of liquid hydrogen, for a total weight of 40t. The fact that liquid hydrogen is dense, and that the cryogenic tanks containing it can have very large

capacities, suggests quite naturally that it should be transported by sea from locations with high production capacity or high consumption. Figure 1.6

The Japanese prototypes are two 200,000m³ cargo ships capable of transporting 14,000t of liquid hydrogen contained in four spherical tanks for one and two prismatic tanks for the other. As for distribution to users, two possibilities are conceivable:

Transfer liquid hydrogen: handling liquid hydrogen is tricky: its temperature is very low and its vapor is flammable. A liquid hydrogen distribution station can therefore be conceived in principle as consisting of a large tank of liquid hydrogen, from which the required quantities are drawn off by gentle pressurization. To reduce transfer times and limit liquid hydrogen consumption, the tank to be filled must not be reheated, i.e. it must not be completely empty of liquid hydrogen - an additional constraint for the user. Replacing the empty tank with a full one would require handling equipment, but the operation, in addition to being relatively quick, could have the advantage of postponing the transfer of liquid hydrogen until the service station's customers are no longer present.

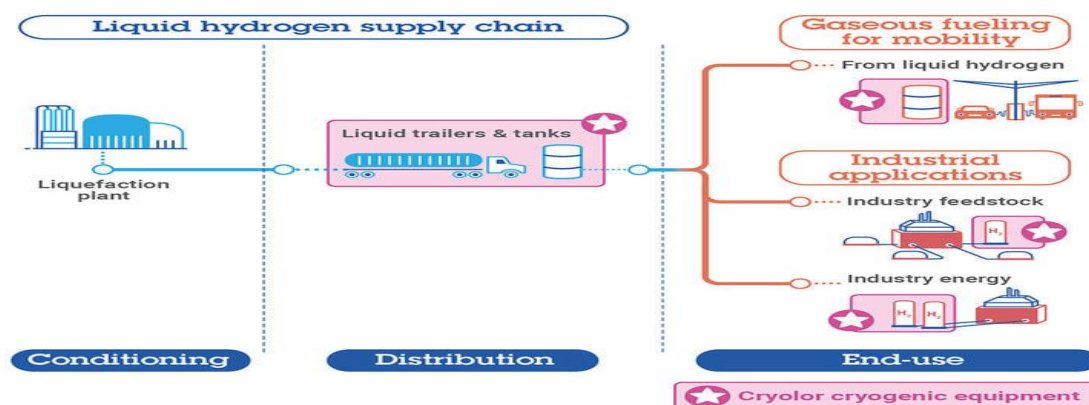


Figure 1.6. Liquid hydrogen transport [19].

1.2.3.3. Solid-state storage and distribution

1.2.3.3.1. Hydrogen storage by adsorption on activated carbons

The most commonly used materials, activated carbons, are made up of graphite microcrystals whose intertwining forms a network of pores with diameters in the nanometer range.

The density per unit area of the carbon atoms making up the pore walls and external surfaces of the microcrystals is the source of the strong attraction exerted by the pore walls on the gas molecules.

In the case of hydrogen, the interaction of the H₂ molecule with the carbon atoms is not very strong, but it is sufficient to ensure that, at a temperature of 293 K and a pressure of 1 bar, the density of adsorbed atoms near the surface of the pore walls is a factor of 10 greater than the density of hydrogen at the same temperature and pressure.

This estimate of the potential of adsorption storage is an upper limit, given the highly favorable pore geometry of the ideal material and the density characteristics of the adsorbed hydrogen. Figure 1.7

Furthermore, at high temperatures, the thermal agitation of the molecules weakens the confining effect of the attractive interaction between molecules and carbon atoms near the walls, reducing the density of the adsorbed layers. [20]

The efficiency of this storage method compared with that based on compression is well established in the temperature range 77 K–150 K and pressures of the order of 100 bar. The gain in storage capacity is of the order of 100% at 77 K and 50% at 150 K. Unfortunately, at room temperature, the gain in efficiency becomes marginal in the 1,200-bar pressure range.

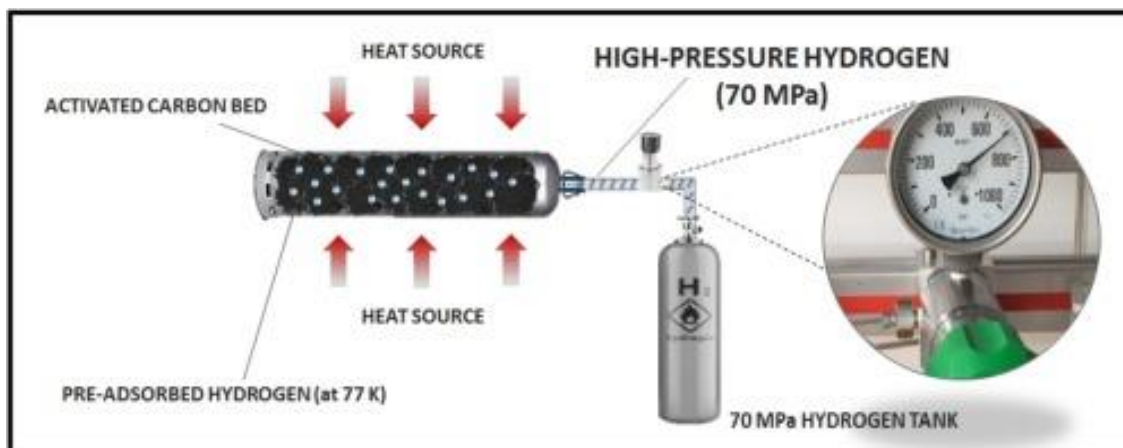


Figure 1.7. Hydrogen thermally driven compressor based on cyclic adsorption-desorption on activated carbon [20].

1.2.3.3.2. Hydrogen storage by adsorption on carbon annotates

As current activated carbons do not seem to have the adsorption capacities to achieve storage that competes advantageously with ordinary temperature compression storage, a great deal of work has been undertaken to estimate the capacities of porous carbonaceous materials whose pore network characteristics approach those of the ideal material mentioned above.

Such materials can be formed by carbon nanotubes.

Carbon nanotubes are obtained by cylindrically winding part of a graphite basal plane.

The diameter of a nanotube increases with the size of the portion of the graphite plane forming its wall.

For the quantity of hydrogen stored in a volume containing a configuration of parallel nanotubes to become similar to or greater than that stored in the same volume by compression, the internal space of the nanotubes must be accessible to hydrogen and the minimum distance between the tube walls of the order of 6\AA .

In practice, while adsorption storage requires large specific surface areas, it also calls for the highest possible bulk density of adsorbents, in order to store as much gas as possible in a given volume. Figure 1.8

This can be achieved by compacting the adsorbents, but this operation is hardly possible with conventional activated carbons; on the other hand, according to initial experiments, it is with nanotubes, an obvious interest for this new material [21].

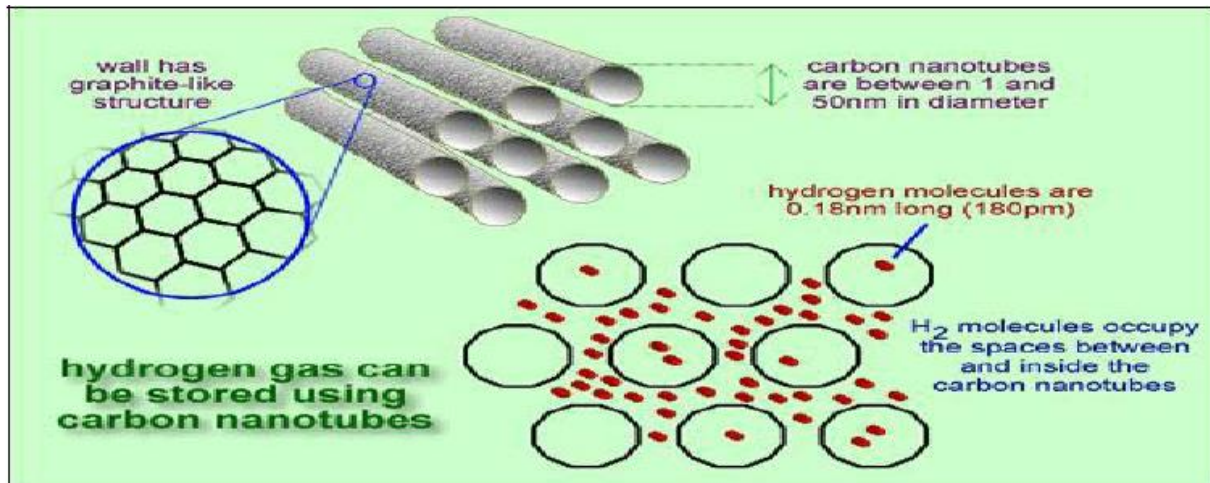


Figure 1.8. Mechanism of CNT for hydrogen storage [21].

1.2.3.3.3 Hydrogen storage in glass beads

Hydrogen storage in hollow glass beads is based on the property of glass to be hydrogen-tight when cold and permeable at high temperatures. The micro beads are introduced into a reactor chamber, heated to 350°C and pressurized with hydrogen. Under these conditions, the gas diffuses inside the bead as the internal and external pressures are balanced. The hydrogen-

filled beads are then cooled and removed from the reactor. The mechanical strength of glass enables them to reach burst pressures of around 1500bars for a diameter of 12 μ m and a thickness of 2 μ m. The hydrogen is released either reversibly, by heating the glass to make it permeable again, or irreversibly, by crushing the beads. This storage method is still in the pure research stage and will not be developed further here.

1.2.3.3.4. Distribution

Hydrogen storage in metal hydrides is three times more efficient than compressed gas, in terms of the ratio of stored quantity to tank volume. On the other hand, due to the high weight of metal hydrides, the percentage of stored weight to tank weight, some 1%, is the most unfavorable of all storage methods. Titanium-based hydride tanks were used in the first Japanese light-duty hydrogen fuel cell vehicles. This was the case as early as 1991 for the Mazda HRX and HRX-2 demonstration cars, and in 1997 for the Demo FCEV. This was also the case for the Honda FCX-V1 (1999) and Toyota RAV4-EV1 and FCHV3 models presented in 1996 and 2001. In addition to these reversible hydride storage systems, Daimler-Chrysler's Natrium prototype (2001) features a special hydride storage system, NaBH₄, which delivers hydrogen through the action of water in the presence of a catalyst. As far as distribution itself is concerned, it is hardly possible to envisage a direct transfer, since the hydrating that corresponds to filling is highly exothermic, requiring energetic cooling of the tank, and is also a slow physic-chemical process. Replacing the empty tank with a full one could be a better solution, provided, once again, that suitable handling equipment is available, given the high weight (100 kg or more) of hydride tanks.

1.2.4. Distribution

Establishing a robust infrastructure for distributing hydrogen is crucial for its widespread adoption as an energy carrier. The distribution of hydrogen involves considerations such as transportation networks, refueling or recharging infrastructure, and decentralized distribution systems.

Hydrogen distribution can take advantage of existing natural gas pipelines, with appropriate modifications to accommodate the different properties of hydrogen. Alternatively, dedicated hydrogen pipelines can be constructed, providing a separate system for the transportation of hydrogen.

For the utilization of hydrogen in fuel cell vehicles, a network of hydrogen refueling stations is necessary. These stations can provide hydrogen to vehicles either through high-pressure dispensers or by producing hydrogen on-site through electrolysis or other methods. The establishment of a reliable and accessible network of refueling stations is crucial for the widespread adoption of hydrogen fuel cell vehicles.

In some cases, decentralized or localized distribution systems may be more suitable, particularly in areas without extensive pipeline infrastructure. These systems can involve on-site hydrogen production using renewable sources, localized storage, and distribution networks, enabling hydrogen to be produced and consumed locally. Figure 1.9

The choice of distribution infrastructure depends on factors such as the scale of hydrogen demand, geographic location, existing infrastructure, future growth projections, and the specific needs of the hydrogen market.

By understanding and optimizing each link in the hydrogen chain – from production to utilization – we can unlock the full potential of hydrogen as a clean and sustainable energy carrier. Continued research, technological advancements, and collaboration between stakeholders will be instrumental in overcoming challenges and realizing the vision of a hydrogen-based energy future [18].

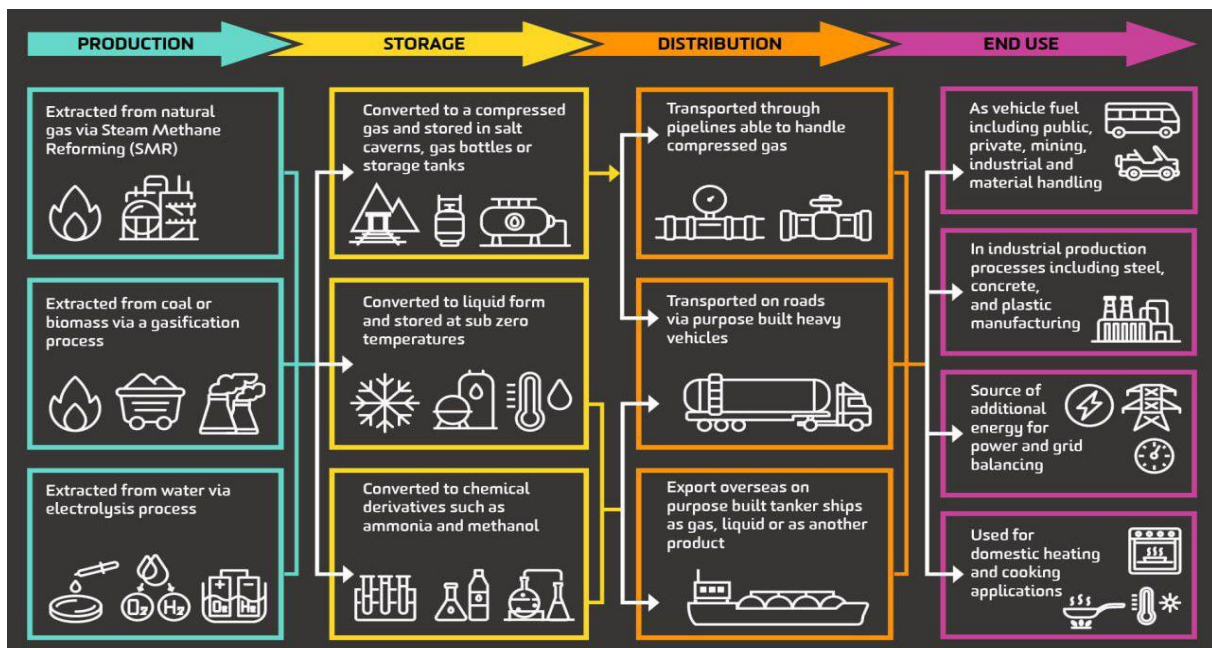


Figure 1.9. Hydrogen supply chain [18].

1.3. Pyrolysis production systems review

1.3.1. Definition

Pyrolysis is a chemical process that involves the decomposition of organic materials through high temperatures in the absence of oxygen. It is a thermal degradation process that converts complex organic compounds into simpler molecules, such as gases, liquids, and solids, without combustion. The word "Pyrolysis" originates from the Greek words "pyro" (meaning fire) and "lysis" (meaning decomposition).

During Pyrolysis, the organic material is heated to temperatures typically ranging from 300 to 900 degrees Celsius (572 to 1652 degrees Fahrenheit) in a controlled environment with limited or no supply of oxygen. In the absence of oxygen, the material does not undergo complete combustion and instead undergoes thermal decomposition. This process breaks down the complex organic molecules into smaller fragments, producing various products depending on the composition of the feedstock and the specific conditions of the Pyrolysis process [22], [23].

Pyrolysis is considered a versatile and potentially sustainable technology for the conversion of biomass, agricultural residues, and waste materials into valuable products. It offers potential benefits such as energy recovery, waste reduction, carbon sequestration, and the production of renewable fuels and chemicals. The specific characteristics of the Pyrolysis products and the overall process efficiency depend on factors such as feedstock composition, heating rate, temperature profile, residence time, and reactor design [24].

1.3.2. Environmental Benefits

- a. Carbon Sequestration:** Pyrolysis enables carbon capture and sequestration by converting biomass into bio char, which can be used as a soil amendment to enhance carbon storage in agricultural lands.
- b. Renewable Energy:** The syngas produced during Pyrolysis can be utilized as a renewable energy source, replacing fossil fuels and reducing greenhouse gas emissions.
- c. Waste Management:** Pyrolysis provides an effective solution for managing various types of organic waste, including agricultural residues, forestry waste, and municipal solid waste, by converting them into valuable products. Figure 1.10

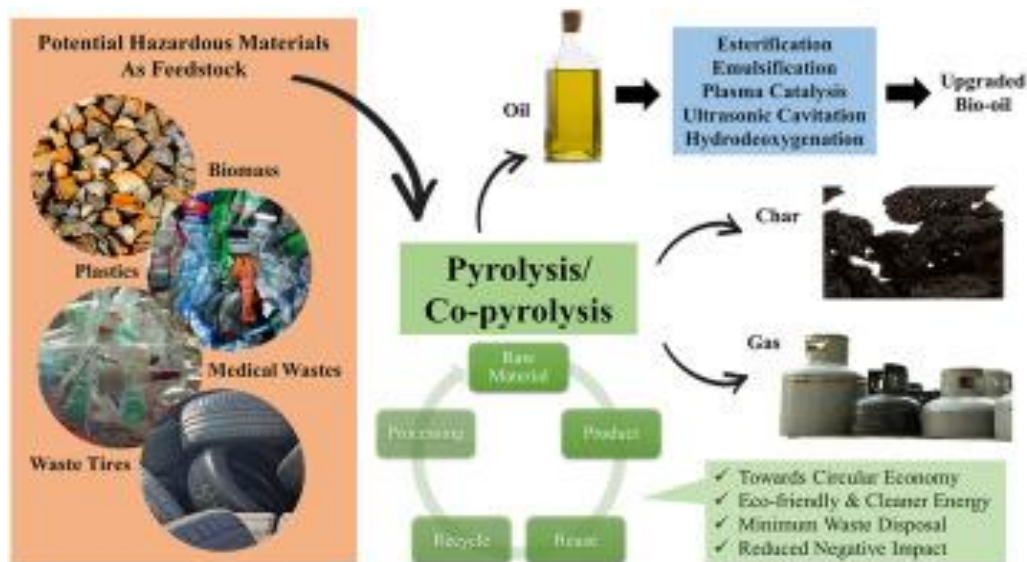


Figure 1.10. Pyrolysis production Environmental Benefits [25].

1.3.2.1. Pyrolysis Production Systems

- a. **Slow Pyrolysis:** This method involves heating biomass at relatively low temperatures (around 400-600°C) for an extended period. It produces higher amounts of bio char and is suitable for carbon sequestration and soil improvement applications.
- b. **Fast Pyrolysis:** Fast Pyrolysis operates at higher temperatures (around 500-800°C) and shorter residence times. It primarily produces bio-oil, which can be further processed into transportation fuels or used in the manufacturing of chemicals and materials.
- c. **Fluidized Bed Pyrolysis:** This system utilizes a fluidized bed reactor where biomass particles are suspended in an upward flow of gas. It offers better heat and mass transfer, resulting in improved product yields and higher energy efficiency.

1.3.2.2. Applications of Pyrolysis Products

- a. **Bio char:** Bio char has diverse applications, including soil amendment for agriculture, carbon sequestration, water filtration, and environmental remediation.
- b. **Bio-oil:** Bio-oil can be processed into renewable transportation fuels or used as a substitute for fossil fuels in industrial applications.
- c. **Syn gas:** Syn gas can be used for heat and electricity generation, as a fuel for gas turbines, or as a precursor for producing chemicals and synthetic fuels.

1.3.2.3. Challenges and Future Outlook

- a. **Technological Advancements:** Further research and development efforts are required to optimize Pyrolysis processes, improve product yields, and enhance energy efficiency.
- b. **Feedstock Availability:** Ensuring a sustainable and abundant supply of biomass feedstock is crucial for the widespread adoption of Pyrolysis production systems.
- c. **Policy Support:** Governments and regulatory bodies play a vital role in promoting the deployment of Pyrolysis technologies through supportive policies, incentives, and funding.

1.3.3. Waste-to-Wealth Potential

- a. **Waste Management:** Pyrolysis offers an effective solution for managing diverse waste streams such as agricultural residues, plastic waste, rubber tires, and municipal solid waste. It allows for the conversion of these wastes into valuable products, reducing the strain on landfills and promoting a circular economy.
- b. **Resource Recovery:** Pyrolysis enables the recovery of valuable resources from waste materials. It transforms waste into high-quality bio char, which can be used as a soil amendment, bio-oil that can be processed into fuels and syngas that can be utilized for energy generation. Figure 1.11
- c. **Economic Opportunities:** The conversion of waste into valuable products through Pyrolysis creates economic opportunities by establishing new industries and markets. It offers the potential for job creation, resource independence, and reduced reliance on traditional fossil fuel sources [26].



Figure 1.11. Turning Waste into Wealth for Growth [26].

1.3.3.1. Pyrolysis Technologies

- a. **Slow Pyrolysis:** Slow Pyrolysis involves heating waste materials at relatively low temperatures (around 400-600°C) for an extended period. This method focuses on maximizing bio char production, making it well-suited for soil improvement and carbon sequestration applications.
- b. **Fast Pyrolysis:** Fast Pyrolysis operates at higher temperatures (around 500-800°C) and shorter residence times. It emphasizes the production of bio-oil, making it suitable for renewable fuel production and chemical feedstock applications.
- c. **Catalytic Pyrolysis:** Catalytic Pyrolysis employs catalysts to enhance the Pyrolysis process, resulting in higher product yields and improved quality. It enables the production of specific chemicals and value-added products from waste materials.

1.3.3.2. Environmental and Social Benefits

- a. **Waste Diversion:** Pyrolysis reduces the amount of waste sent to landfills, mitigating environmental pollution and minimizing greenhouse gas emissions.
- b. **Energy Generation:** Syngas produced during Pyrolysis can be used to generate heat and electricity, providing a renewable energy source and reducing reliance on fossil fuels.

- c. Soil Improvement: The application of bio char derived from Pyrolysis improves soil fertility, water retention, and nutrient cycling, promoting sustainable agriculture practices.
- d. Job Creation: The development and operation of Pyrolysis facilities create employment opportunities in waste management, technology development, and downstream industries.

1.3.3.3. Challenges and Future Outlook

- a. Technology Optimization: Continuous research and development efforts are needed to enhance Pyrolysis technologies, improve process efficiency, and maximize resource recovery.
- b. Feedstock Availability: Ensuring a consistent supply of suitable waste feedstock is crucial for the widespread adoption of Pyrolysis. Collaboration with waste management systems and policies can facilitate feedstock availability.
- c. Regulatory Support: Governments and regulatory bodies should provide supportive policies, incentives, and regulations to encourage the adoption of Pyrolysis as a waste management and resource recovery solution.

1.3.4. Products of Pyrolysis

The Pyrolysis process generates several valuable products of which (bio char, bio oil and syn gas) as show in the figure 1.12:

- a. Bio char: Bio char is a carbon-rich solid material similar to charcoal. It has excellent potential as a soil amendment, enhancing soil fertility, water retention, and nutrient absorption. Bio char also sequesters carbon, contributing to climate change mitigation.
- b. Bio-oil: Also known as Pyrolysis oil or bio crude, bio-oil is a dark liquid with similar properties to conventional fossil fuels. It can be further refined and used as a substitute for petroleum-based fuels, such as gasoline or diesel. [27]
- C.Syn-gas: short for synthesis gas is a mixture of carbon monoxide and hydrogen, usually produced by the gasification of biomass or fossil fuels. It's a versatile feedstock used in various industrial processes, including the production of fuels, chemicals, and electricity.

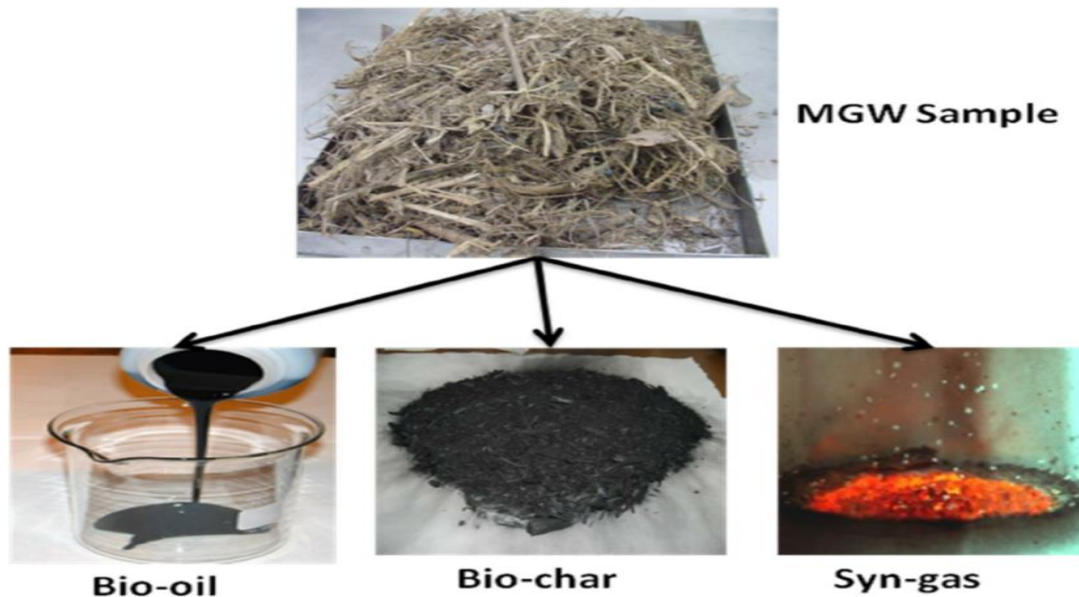


Figure 1.12. MGW Pyrolysis products (Bio-oil, Bio-char, Syn-gas) [27].

1.3.5. Advantages of Pyrolysis

1. Renewable Energy Generation
2. Waste Management
3. Carbon Sequestration

1.3.6. Applications of Pyrolysis

1. Bio fuel Production: The bio-oil obtained from Pyrolysis can be further refined into transportation fuels, such as gasoline, diesel, and jet fuel. These bio fuels have the potential to replace fossil fuels in various sectors, reducing carbon emissions and promoting energy independence.
2. Heat and Power Generation: The syngas produced during Pyrolysis can be utilized for heat and power generation through combustion or gasification. Syngas can fuel engines, turbines, and boilers, providing a renewable energy source for industrial processes and electricity production.
3. Agricultural and Environmental Applications: Bio char produced from Pyrolysis has multiple agricultural applications. It can improve soil quality, enhance water retention, and promote nutrient cycling. Additionally, bio char can be used in environmental remediation projects to capture and store pollutants [23].

Challenges and Future Outlook: While Pyrolysis holds great promise; several challenges need to be addressed for its widespread adoption. These challenges include the scalability of Pyrolysis technologies, feedstock availability, and economic viability. Research and

development efforts are focused on improving Pyrolysis processes, optimizing feedstock selection, and reducing production costs.

Despite the challenges, the future outlook for Pyrolysis is optimistic. The technology has the potential to transform waste management systems, promote renewable energy generation, and contribute to sustainable development. Continued advancements and increased support from governments and industries will be instrumental in realizing the full potential of Pyrolysis in the renewable energy revolution.

Syngas: Syngas, or synthesis gas, is a mixture of carbon monoxide, hydrogen, and other gases. It can be used as a fuel for heat and power generation or as a feedstock for the production of chemicals and fertilizers.

Specialty Chemicals: Pyrolysis can also yield various specialty chemicals, depending on the feedstock used. These chemicals can have applications in industries such as pharmaceuticals, plastics, and agriculture.

1.4. Biomass description

1.4.1. Definition

Biomass refers to all living matter, including organic matter from plants, animals, insects, and microorganisms, as well as organic waste. It is primarily produced through photosynthesis and is composed of complex carbon-based polymers. The definition of biomass varies depending on the context, but for energy purposes, it is defined as the biodegradable portion of biological products, waste, and residues from various industries. In the specific study mentioned, the focus is on dry biomass, also known as lignocelluloses biomass, which includes wood wastes, agricultural residues, and other materials used for energy or agronomic purposes. This type of biomass is characterized by its composition, which includes cellulose, hemicelluloses, lignin, extractives, and ash [28]-[30].

1.4. 2.The principle of biomass

The principle of action of biomass is on a biomass power plant plan; see the following figure 1.13:

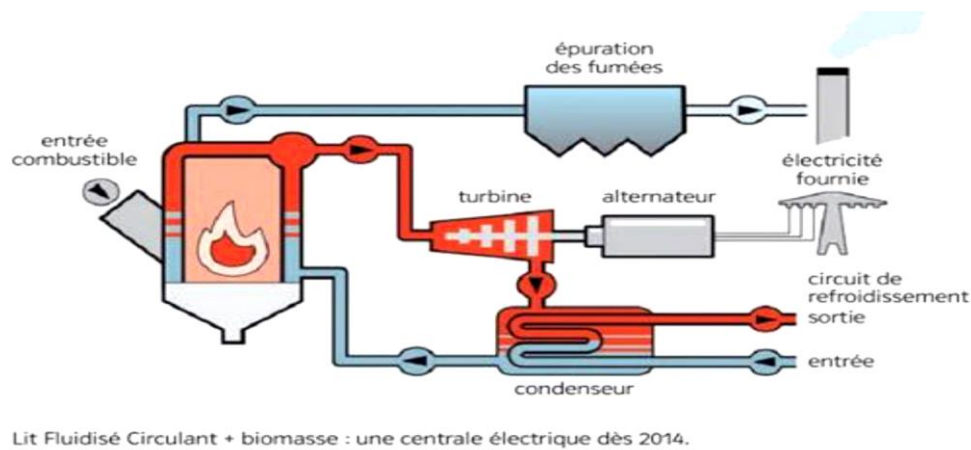


Figure 1.13. How a biomass power plant works [29].

First, the biomass is burned this process produces a high temperature which transforms the water into steam, then electricity is produced thanks to the turbines which provide energy to the generator [29].

1.4.3. Elemental composition of biomass

Biomass is an organic compound composed primarily of carbon, hydrogen, oxygen, nitrogen, and mineral matter. The proportions of carbon, hydrogen, and oxygen in biomass are relatively consistent, with around 50% carbon, 40% oxygen, and 6% hydrogen. Nitrogen is present in smaller amounts, typically ranging from 0.4% to 1.2 %.(Table 1) Biomass can vary in its mineral matter content, with woods generally containing low levels. The mineral matter in biomass can differ in composition across different types and is often found as salts or inorganic species bound to organic compounds. In comparison, fossil fuels have higher concentrations of carbon, hydrogen, and oxygen due to their hydrocarbon content. Biomass also contains trace amounts of nitrogen, sulfur, and chlorine, which impact pollutant emissions. However, their quantities are typically lower in biomass, resulting in cleaner fuels. Elemental analysis, including chlorine content evaluation, is crucial for assessing the calorific value and combustion requirements of biomass, with moisture and ash content also influencing conversion processes. [30]-[31].

Table 1: Elemental Composition of Typical Biomass as derived from Ultimate Analyses.

Element	Symbol	Weight percent(dry and ash-free bases)
Carbon	C	44-51
humidity	H	5.5-6.7
Oxygen	O	41-50
Nitrogen	N	0.12-0.60
Sulphur	S	0-0.2

1.4.4. Composes de la biomasselingo-cellulosique

A lignocelluloses biomass primarily consists of cellulose, hemicelluloses, and lignin, along with small amounts of mineral matter and extractable. Figure (1.14), the complex arrangement of these components can be observed in wood, where cellulose is concentrated inside the fiber, the outer fiber walls consist mainly of lignin and hemicelluloses, and the fiber junctions are composed almost entirely of lignin. Pectin, a network of acidic polysaccharides, further adds to the matrix's complexity, along with secondary networks of hydroxyl proline-rich glycoprotein's (HRGP). The proportions of cellulose, hemicelluloses, and lignin vary considerably across different biomasses. Thermo chemical processes, such as combustion, Pyrolysis, and gasification, are employed to energetically utilize biomass, with each process utilizing different oxidizing agents. However, liquefaction is still in the research and development phase and lacks industrial-scale implementation [28]-[30].

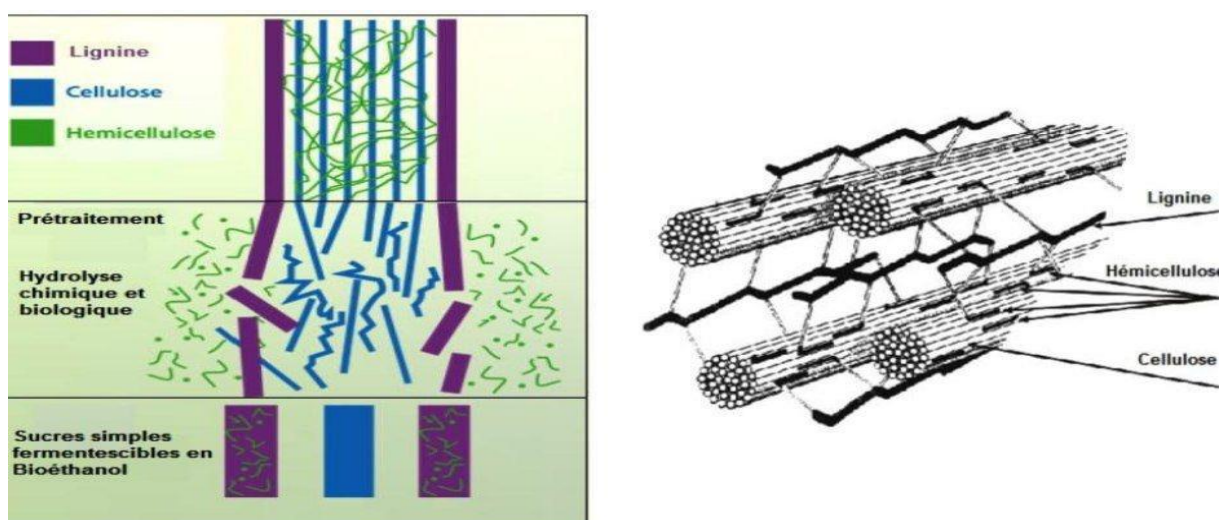


Figure 1.14. Constituents of lignocelluloses material and schematic results of the proceeds [30].

1.4.4.1. Cellulose

Cellulose is a high molecular weight linear polymer composed of glucose monomers connected by β -(1, 4) glycoside bonds. It forms semi crystalline micro fibrils that organize into layers, constituting the plant cell wall. Cellulose is resistant to mechanical stress and insoluble in water and most solvents due to its hydrogen-bonded structure. It is part of the holocellulose complex, along with hemicelluloses. Cellulose is the main component of the skeletal membrane in plant cells and plays a crucial role in providing strength and rigidity. Despite its well-known chemical structure, the complete understanding of its fibrous and crystalline nature is still being explored.

1.4.4.2. Hemicelluloses

Hemicelluloses are soluble polysaccharide polymers found in the cell walls of plants, particularly in wood and plant tissues. They can be extracted from the cell wall using acidic solutions and are characterized by their diverse composition and branching structures. Hemicelluloses consist of various monomer units, including hexodes (glucose, mannose, galactose) and pentose's (xylose, arabinose, fructose), with xylose being the most abundant monomer. While there are no direct chemical bonds between cellulose and hemicelluloses, weak interactions such as hydrogen bonding and Van der Waals forces exist. Common hemicelluloses in wood cell walls include xylans, mannans, and galactans, which have linear main chains composed of xylose, mannose, and galactose, respectively.

1.4.4.3. Lignin

Lignin is a complex, amorphous, and relatively hydrophobic polymer comprised of three major monomers: coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol, all characterized by a benzene ring in their structure. It fills the space between cellulose and hemicelluloses in plant cell walls, providing rigidity. The exact chemical structure and molecular weight of lignin depend on the biomass type, making it challenging to isolate native lignin without degradation. However, approximate molecular weight ranges have been estimated, with hardwood lignin averaging 5,000 to 10,000 g/mol and softwood lignin around 20,000 g/mol.

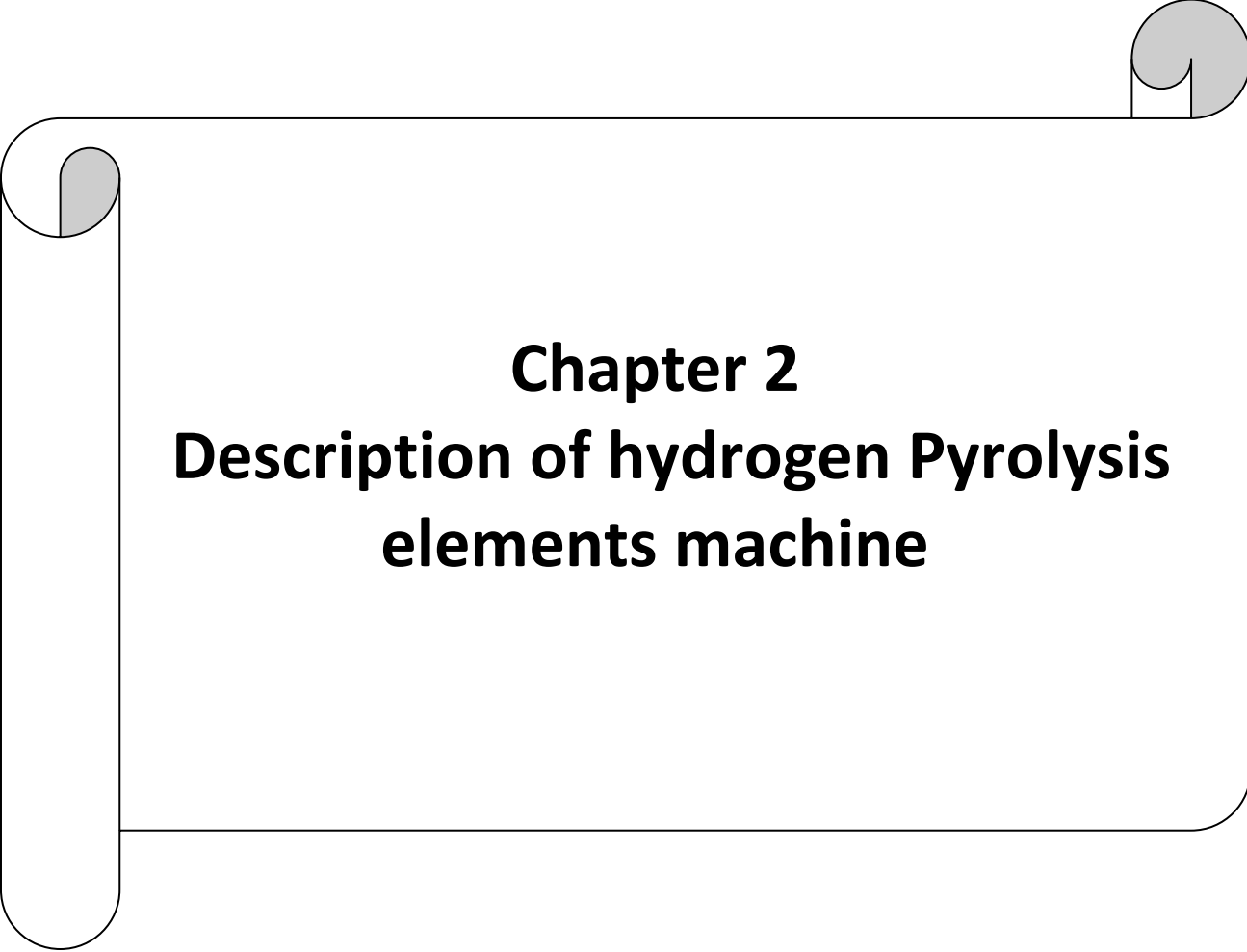
1.4.5. The role of mechanical engineering for pyrolysis of biomass from palm waste

In the Pyrolysis of biomass from palm waste, mechanical engineering plays a crucial role in designing, optimizing, and operating Pyrolysis equipment such as reactors, feed systems, and collection systems. Mechanical engineers are responsible for developing efficient heat transfer mechanisms, designing robust reactors to withstand high temperatures and pressures, and ensuring proper mixing and agitation of the biomass feedstock. Additionally, mechanical engineers contribute to the development of control systems to regulate temperature, pressure, and flow rates throughout the Pyrolysis process. This ensures the efficient conversion of palm waste biomass into valuable products such as bio-oil, bio-char, and syn gas [32].

1.5. Conclusion

We have discussed the importance of hydrogen as an energy carrier, the different production methods, transport options, storage techniques, and distribution infrastructure. Additionally, we have explored the concept of pyrolysis production systems and provided an overview of biomass as a feedstock for hydrogen production. This chapter sets the foundation for understanding the key aspects of the hydrogen supply chain.

The second chapter will treat the description of the hydrogen element pyrolysis machine



Chapter 2
Description of hydrogen Pyrolysis
elements machine

2.1. Introduction

The hydrogen Pyrolysis elements machine is an intricate device designed specifically for the process of hydrogen Pyrolysis, which entails the breakdown of hydrogen molecules into their fundamental elements, namely hydrogen atoms. This machine employs a combination of external and internal functional analyses to comprehensively understand its operational dynamics and enhance its efficiency. Externally, factors such as environmental conditions, input variables, and output parameters are scrutinized to ensure optimal performance. Internally, the intricate mechanisms and components within the machine are thoroughly examined to identify potential areas for improvement and innovation. Through a holistic approach to analysis and optimization, the hydrogen Pyrolysis elements machine stands as a testament to cutting-edge technology in the realm of hydrogen processing, Since in value analysis the product is considered a set of functions and not a set of parts, the study of these functions is according to an analytical methodology called functional analysis. [31]

2.2. Functional Analysis

2.2.1. Definition

Functional analysis is a method of counting, distinguishing, arranging, sequencing and evaluating product functions.

2.3. Functional analysis methodology

2.3.1. Expressing the need

The customer is the one who expresses the need and highlights the manufacture of the product or the completion of the service, and this is done through the notebook of conditions.

2.3.2. Study

Starting from the notebook of conditions, where the overall function is highlighted, it takes place:

* Study of the product.

Highlighting service functions.

*Study of product ingredients.

Highlighting jobs.

2.3.3: Making a product or performing a service

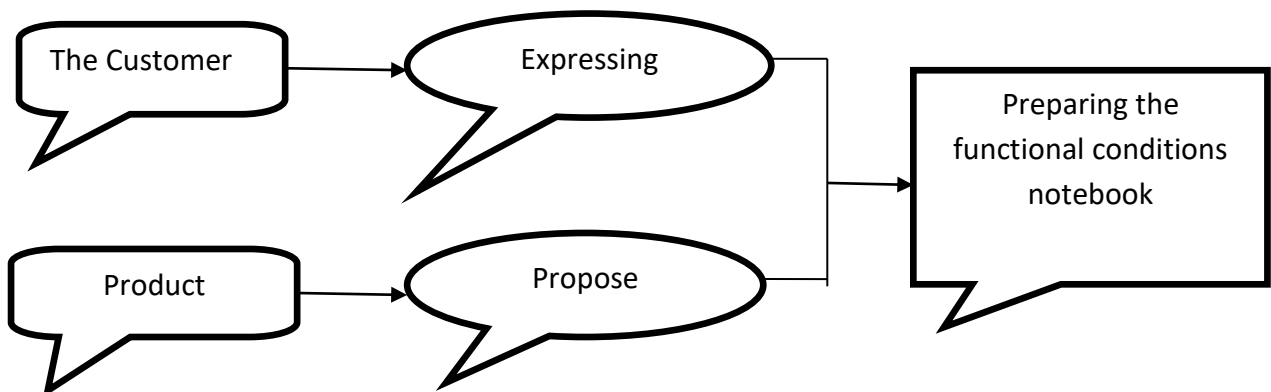
- Making components.

-Assemble the components.

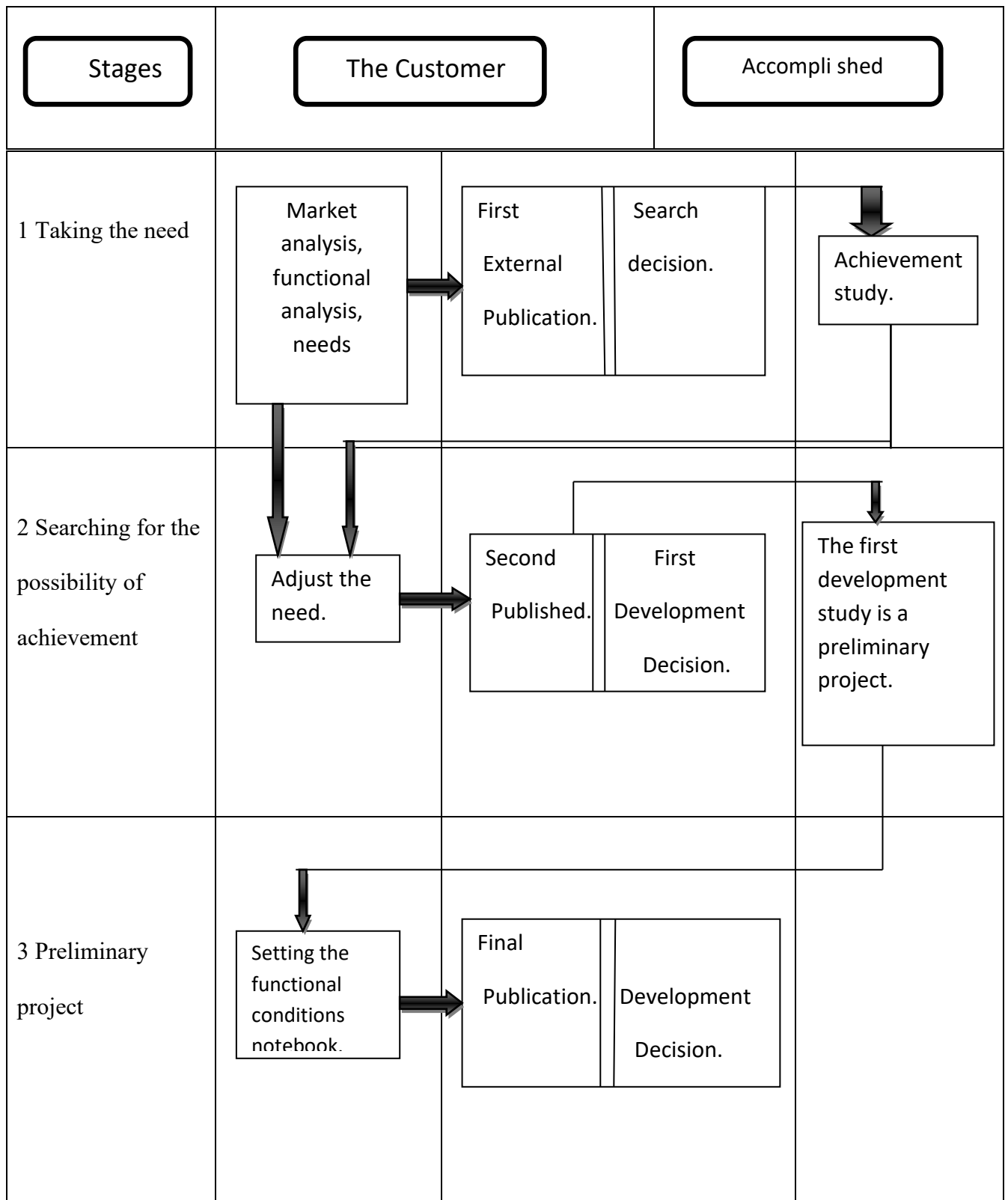
-Complete a service.

2.4. Functional notebook of specifications

The functional notebook of specifications is a document through which the customer expresses his desires and needs in the form of service jobs. The functional notebook of conditions aims to be able to propose a product capable of meeting the need at the lowest cost. It also contributes to clarifying responsibilities (relationship: customer - completed designer).



2.5. Preparing the employment conditions notebook



Flowchart 2.1. Employment conditions notebook steps

2.6. Analysis tools

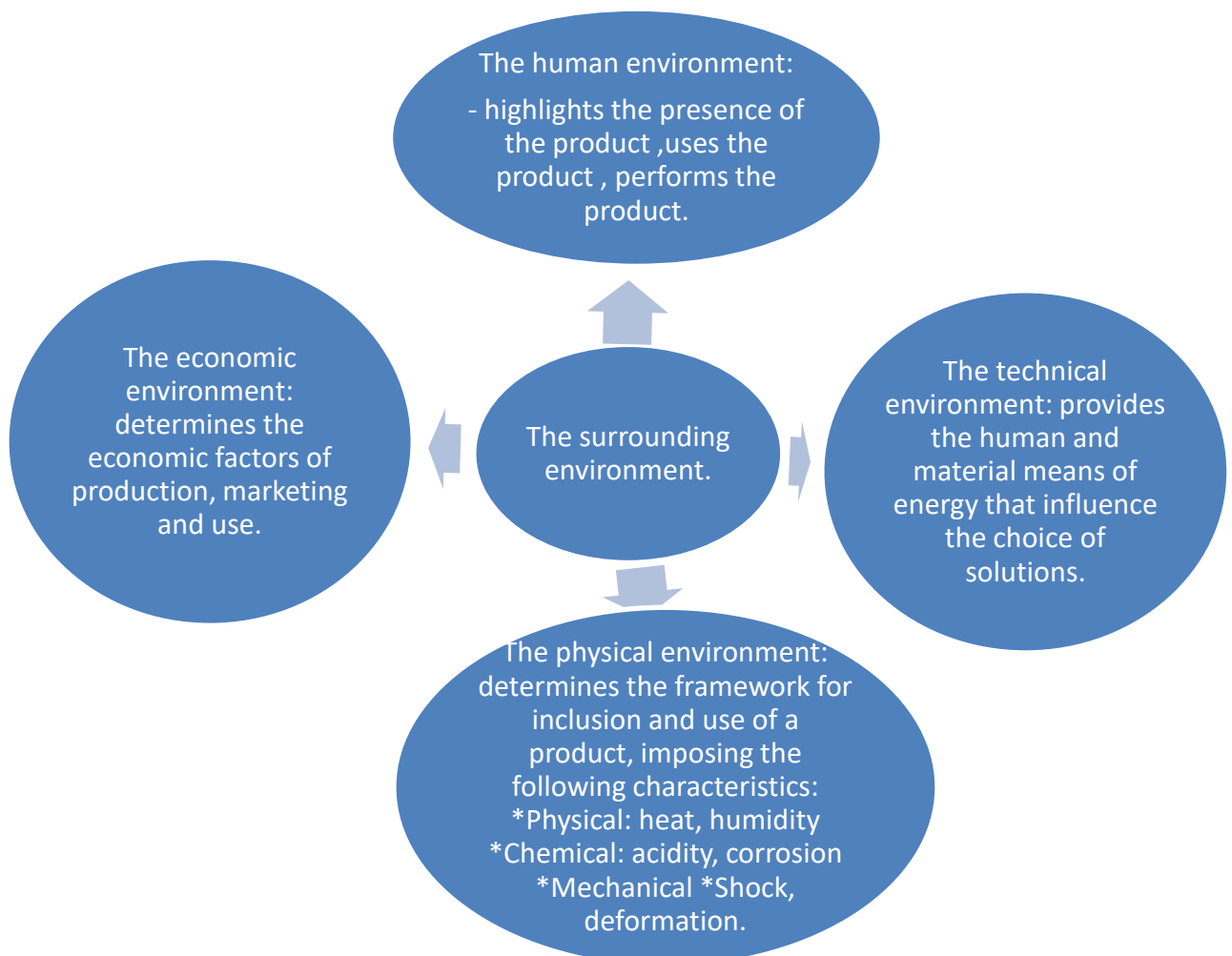
2.6.1. Overall functionality of the product

2.6.1.1. Definition

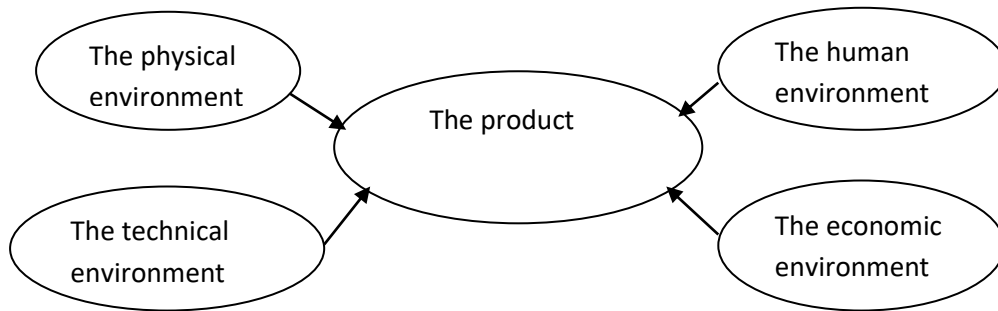
It is the function that conforms to the nature of the material without taking into account the internal organization of the product.

2.6.2. The surrounding environment

All products are subject to conditions imposed by the surrounding environment. We call the surrounding environment or the outer environment of a product all the material or non-material elements that constitute the human, physical, economic and technical components that are related to the product.



2.6.3. Assembly chart



2.7. External Functional Analysis

The external functional analysis of the hydrogen pyrolysis elements machine can be represented using two diagrams: the Horned Beast diagram and the Octopus diagram.

2.7.1. Horned Beast Diagram

The Horned Beast diagram provides a high-level overview of the machine's external functionalities and their interrelationships. It typically includes inputs, outputs, controls, and mechanisms involved in the hydrogen pyrolysis process. The diagram helps visualize the overall operation and external interactions of the machine. Figure 2.1

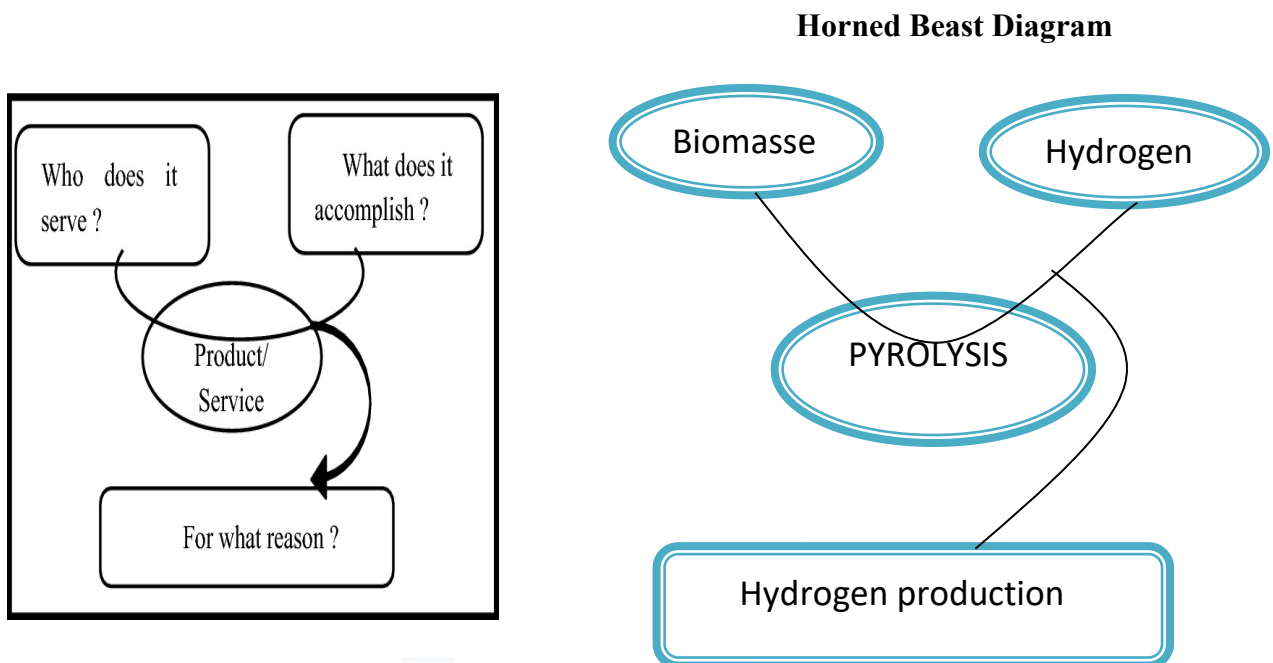


Figure 2.1. The Horned beast [32]

2.7.2. Imperatives:

2.7.2.1. Definition:

Imperatives (mandatory) are limits that restrict the freedom of the completed designer, for example:

- Security.
- Respect for the environment (surroundings).
- Duration of completion.
- Interchange ability (exchangeability).
- Respect for standards, system and laws.
- Market (need requirements for an objective cost).

2.7.3. Octopus Diagram:

The Octopus diagram further expands on the external functional analysis by depicting the machine's various components and their relationships in a more detailed manner. It illustrates How different parts of the machine interact with each other and with the external environment during the hydrogen pyrolysis process. Figure 2.2

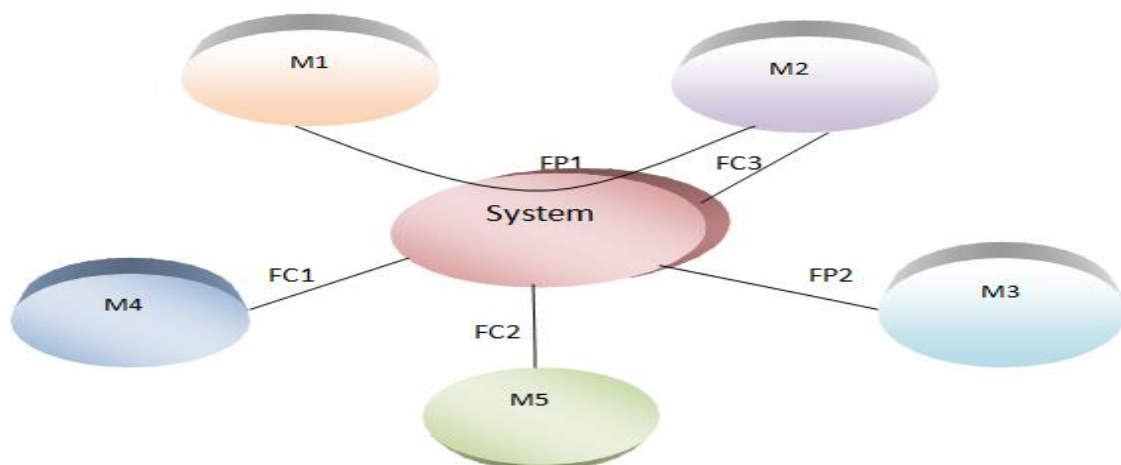


Figure 2.2. The octopus.

Octopus Diagram:

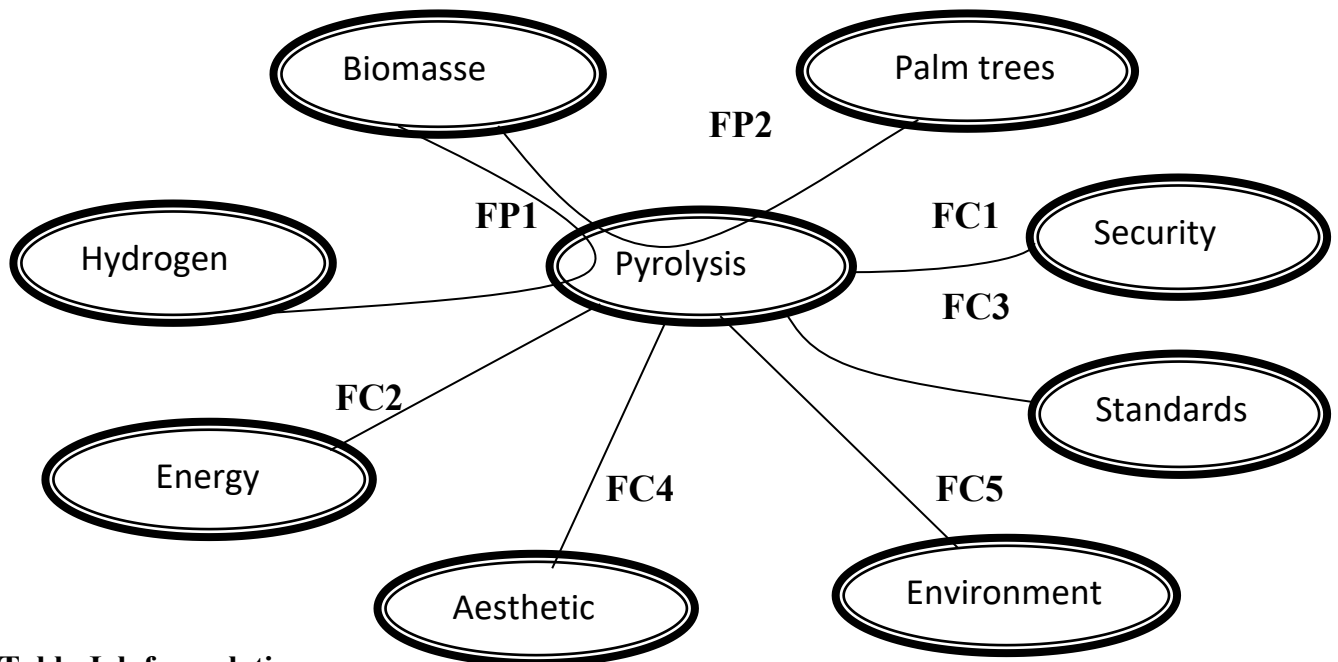


Table Job formulation:

FP1	Hydrogen extraction by biomass.
FP2	Obtain biomass through palm trees
FC1	Providing safety for workers and the environment.
FC2	It works under the electricity voltage.
FC3	Ensuring direct communication in the event of a malfunction.
FC4	It should have an appearance and color that matches the surrounding decor.
FC5	Capture burned gases.

2.8. Internal Functional Analysis

The internal functional analysis of the hydrogen pyrolysis elements machine involves examining its internal components and their interactions. Two commonly used diagrams for internal functional analysis are the FAST (Function Analysis System Technique) diagram and the DAST (Design and Analysis System Technique) diagram.

2.8.1. FAST Diagram

The FAST diagram breaks down the machine's internal functions into hierarchical levels. It identifies the main functions and sub-functions performed by different components of the machine. This diagram helps in understanding the internal flow of actions and the relationships between various functional elements.

- The main functions, of a higher level, are on the left: they represent why, the need,
- The technical functions and sub-functions are on their right, of a lower level, they represent the "how to accomplish the main functions, to achieve the desired result",
- Those that have a link are on top of each other, they represent the interdependencies And simultaneity, the when, which is therefore not temporal. Figure 2.3

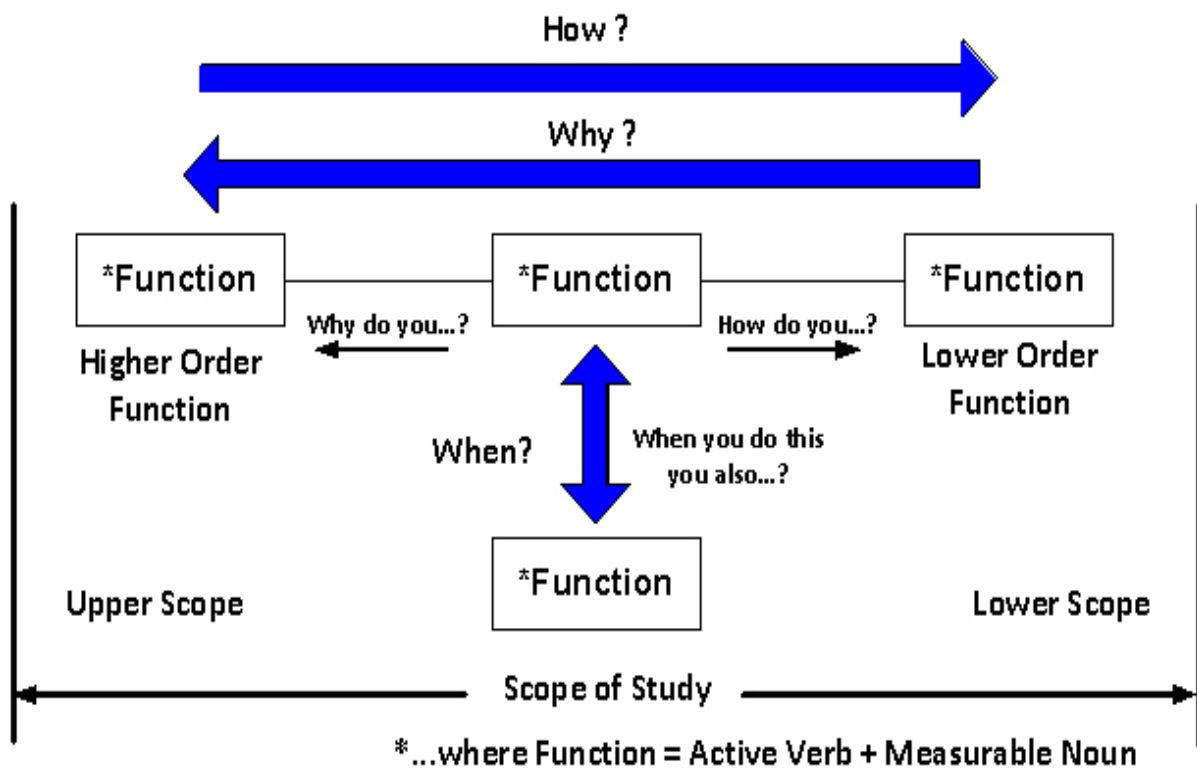
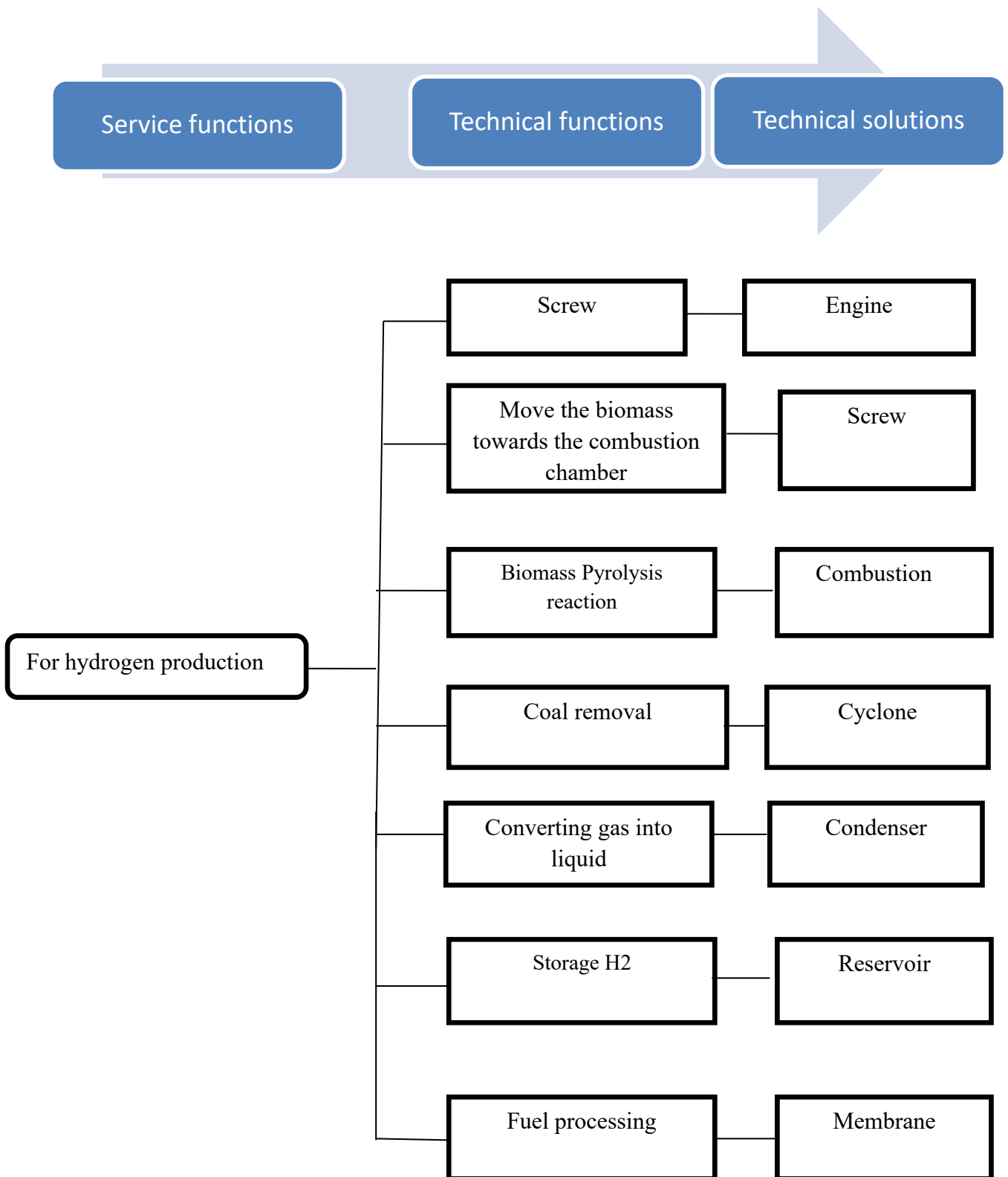


Figure 2.3. The function analysis system technique [33]

FAST Diagram



2.8.2. DAST Diagram

The DAST diagram provides a more detailed representation of the machine's internal functional analysis. It focuses on the functional relationships between different components and subsystems of the machine. The diagram helps in analyzing the design and performance of the machine's internal elements. Figure 2.4

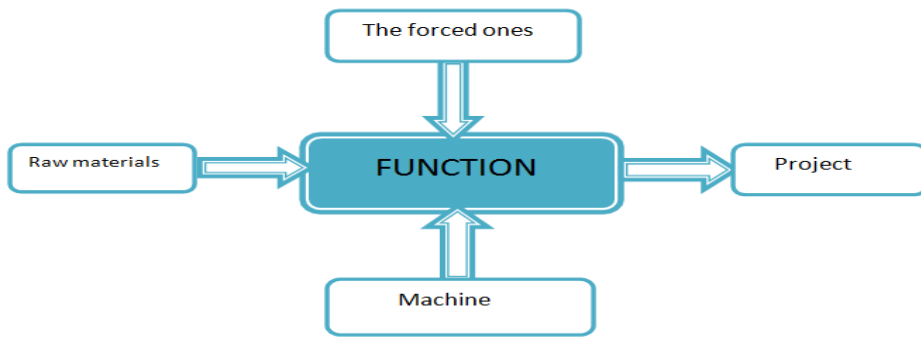
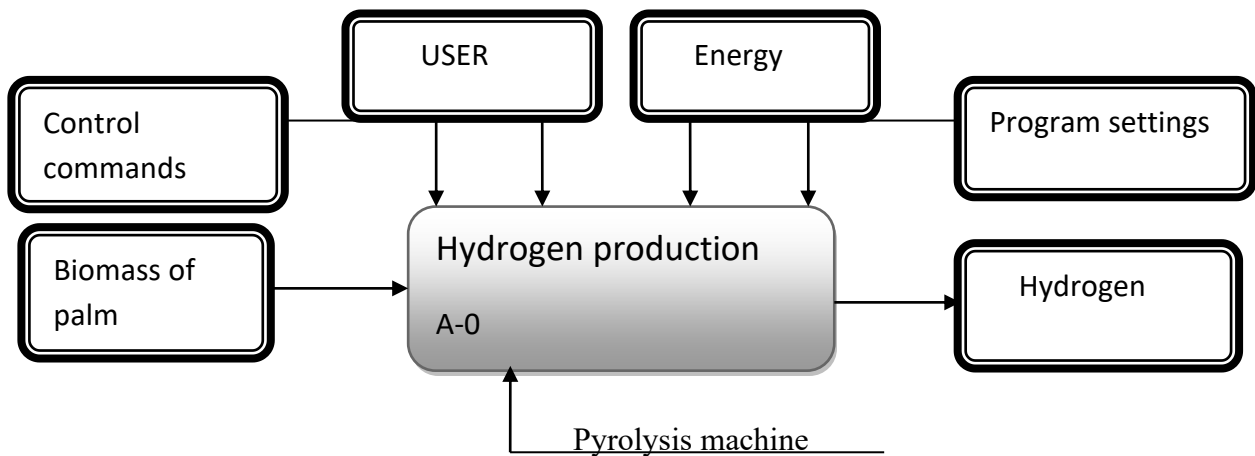


Figure 2.4. The design and Analysis System Technique.

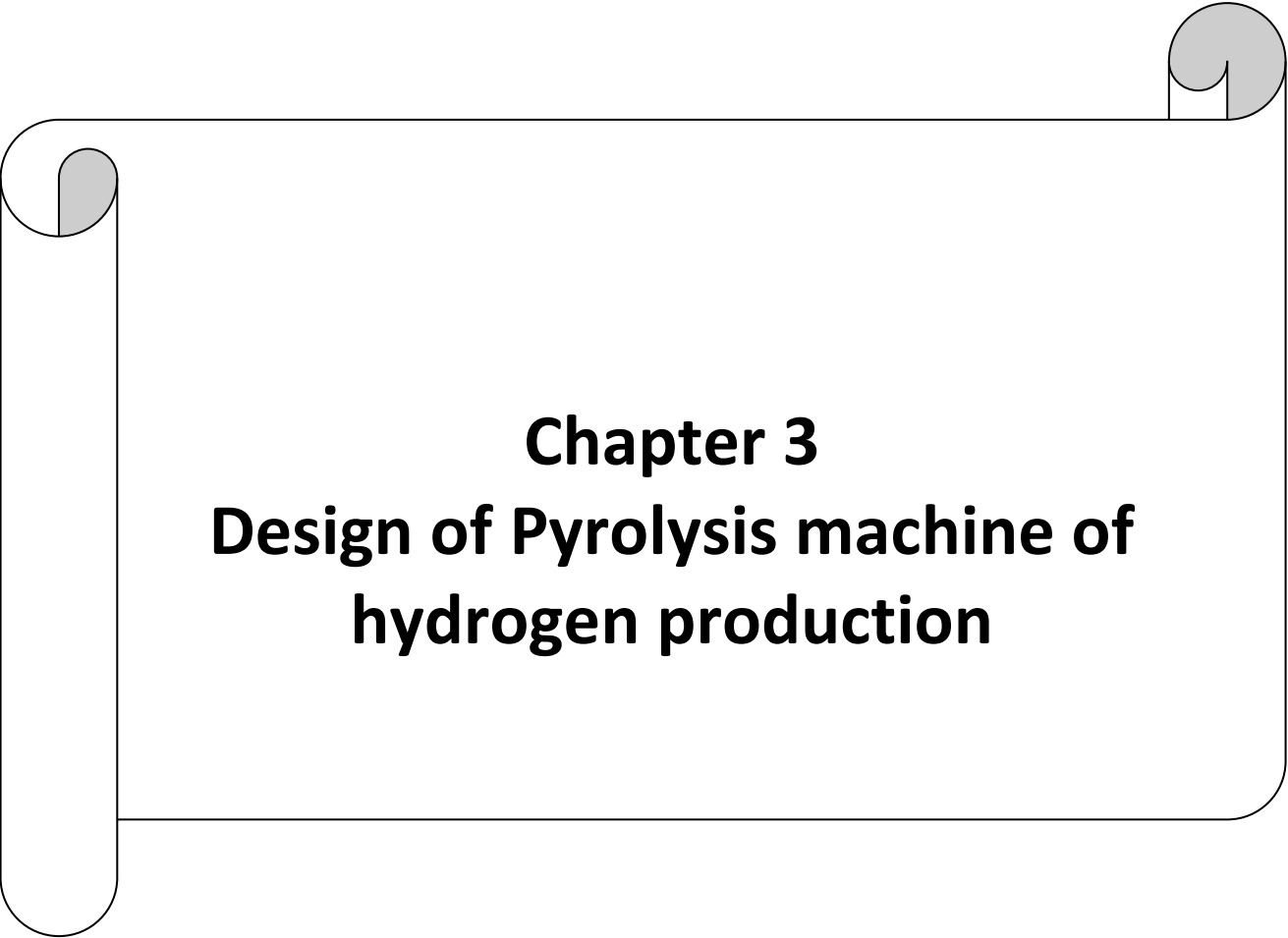
DAST Diagram



Especially for hydrogen production

2.9. Conclusion

Overall, through external functional analysis using the Horned Beast and Octopus diagrams, and internal functional analysis using the FAST and DAST diagrams, the hydrogen pyrolysis elements machine can be thoroughly studied and optimized for efficient hydrogen pyrolysis operations.



Chapter 3
**Design of Pyrolysis machine of
hydrogen production**

3.1. Introduction

It is a thermal decomposition process carried out in the absence of oxygen, which breaks down organic materials into smaller molecules. The primary products of pyrolysis include solid waste (coal), liquid (bio-oil), and gaseous components (syngas), from which hydrogen can be extracted. The mechanical design of the machine is implemented on solid works software. A well-designed pyrolysis machine can optimize hydrogen production while reducing unwanted by-products.

3.2. CAO computer-aided design

Figure 3.1, CAO is one of the most commonly used software design tools. Models created with CAO software are often used as the basis for other design and mechanical engineering tools. CAO, or computer-aided design and drafting, is based on a design and technical documentation technology that replaces manual drafting with an automatic process. [34]

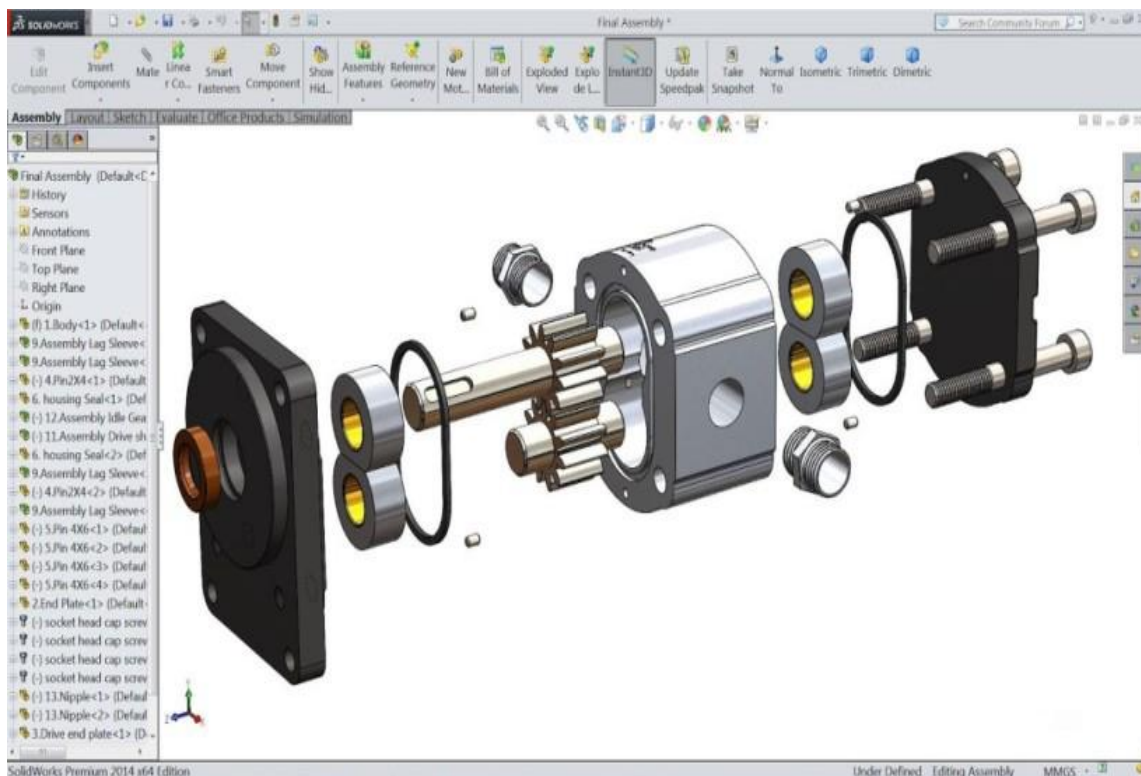


Figure 3.1. Example of Solid work interface for computer-aided design Computer [34].

3.4. Solid Works software

Solid Works is computer-aided design software based on a 3D geometric modeler capable of modeling complex shapes. In fact, Solid Works modeling is based on dimensioned sketches, which allow you to specify object distances and measurements very precisely, with the option of modifying these values via the Solid Works history. This makes modeling both precise and flexible. We chose to use this software because it is capable of realizing the different shapes of our machine components; moreover, it enables us to save the 3D model in various neutral formats, so that we can carry out further studies using other software packages, such as.

3.4.1. Operating mode

Types of files relating to three basic concepts: the part, the assembly and the drawing. These files are interrelated. Any modification at any level of the processed file Will is reflected directly in all the files concerned. Figure 3.2

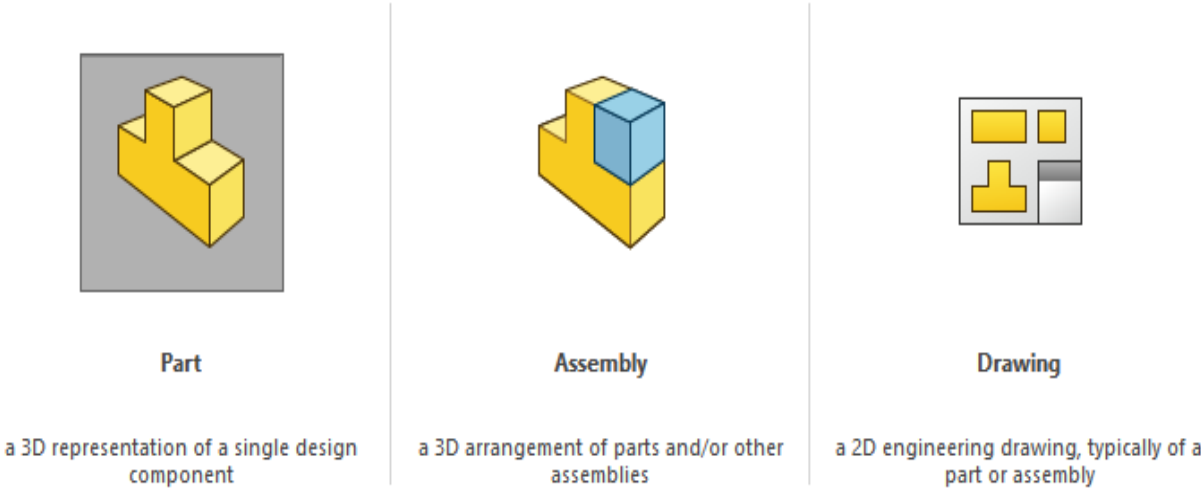


Figure 3.2. Solid Works basic concepts [34].

3.5. Main components of pyrolysis machine

1. Raw material preparation unit:

- Function: Pre-treatment of raw materials to ensure optimal pyrolysis homogeneity and size.
- Components: cutting machines, dryers, and conveyors.

2. Pyrolysis reactor:

- Function: thermal decomposition of feedstocks under controlled conditions.
- Design types: fixed bed, fluidized bed, rotary kiln, or perforated reactors.
- Material: High temperature resistant alloy or ceramic.
- Heating method: direct (flame) or indirect (electric, microwave).

3. Condensation system:

- Function: Separating and collecting bio-oil from pyrolysis fumes.
- Components: condensers, heat exchangers, collection tanks.

4. Gas separation unit:

- Function: Purification and extraction of hydrogen from synthetic gas.
- Techniques: pressure swing adsorption (PSA), membrane separation, cryogenic distillation.

5. Coal handling system:

- Function: Collect and process solid waste (coal) for disposal or further use.
- Components: screw conveyors, cooling systems, storage boxes.

6. Control system:

- Function: Monitor and control operating parameters (temperature, pressure, feed rate).
- Components: Sensors, PLCs (programmable logic controllers), HMI (human-machine interface).

7. Safety Features:

Chapter 3 Design of Pyrolysis machine of hydrogen production

- Function: Ensure safe operation of the machine.
- Components: pressure relief valves, gas detectors, fire extinguishing systems.

3.6. Operating Parameters

1. Temperature: Typically ranging from 400°C to 450°C depending on the raw material and hydrogen yield required.
2. Pressure: Generally atmospheric pressure, but can vary for specific raw materials.
3. Residence time: Duration of feedstock in the reactor, which affects product distribution.
4. Heating rate: Fast heating rates increase gas production including hydrogen.

3.7. Elements of the pyrolysis machine that form the stages

3.7.1. Biomass energy system

It consists of a pyramid-shaped silo with a rectangular base that this silo can contain Up to 50 kg of palm waste. At its lower end there is an endless screw attached to it the electric motor allows the pyrolysis machine to be supplied with biomass at a flow rate Adjustable according to optimal operating conditions see Figure 3.3.

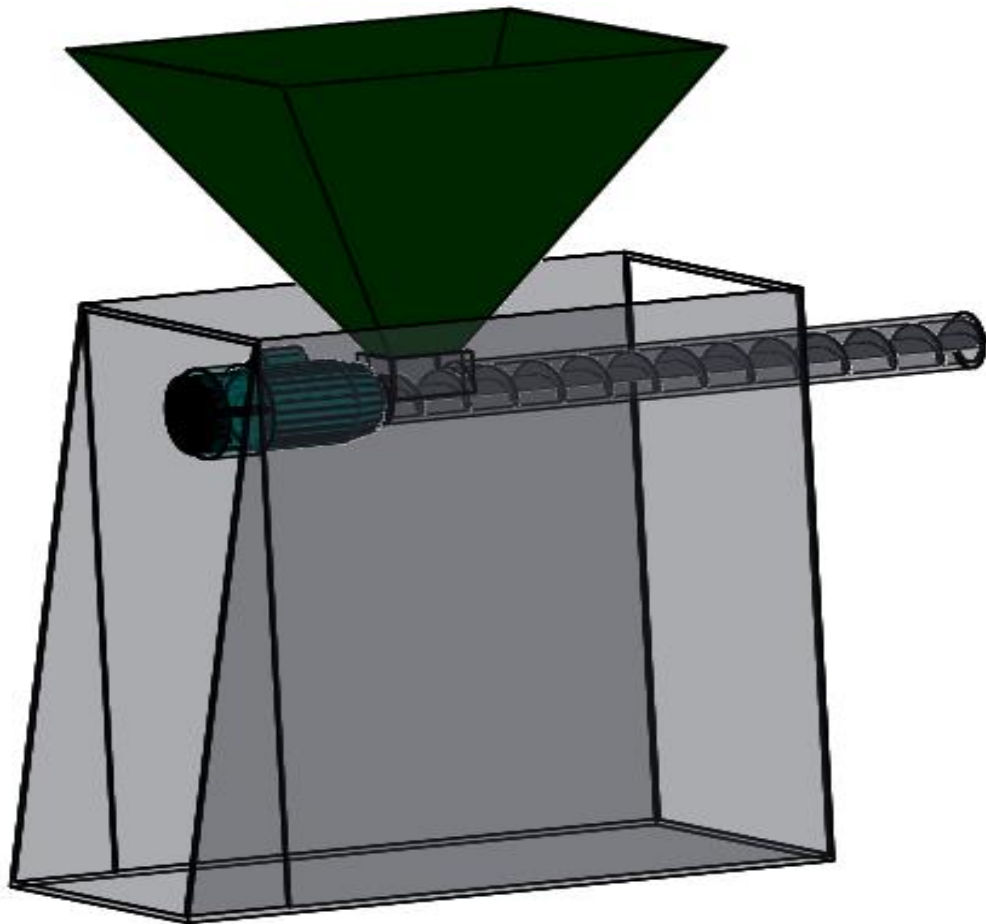


Figure 3.3. Feeder silo.

3.7.2. Air supply system

It consists of a fan and a power circuit. Allow fan to supply air to the pyrolysis machine at the exact flow rate specified in the calculation section Playoffs. The supply circuit in our case is a stainless-steel tube which should be avoided Problems associated with high temperatures in the combustion chamber as you can see in Figure 3.4. The air is distributed through a conical part for better air circulation Flammable air mixture



Figure 3.4. Air supply system.

3.7.3. Grille and ashtray

This is the part that determines the type of biomass pyrolysis, there are several types starting from rack furnaces to pulverized fuels. Complex types of ovens are not profitable only large-scale pyrolysis, to treat this we will choose the simplest type to know: fixed rack oven. This type of oven consists of a grate that is placed over an ashtray for evacuation Ash; Figure 3.5 shows the ashtray and the grid.

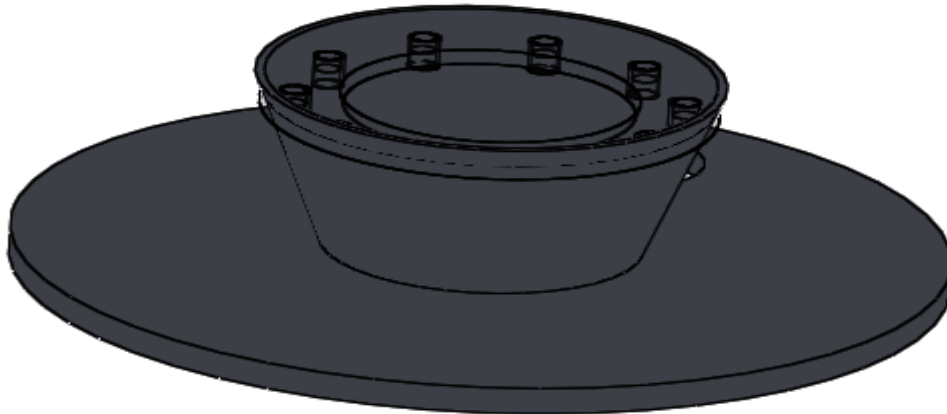


Figure 3.5. Streamer.

3.7.4. Endless screw

This type of screw is called an Archimedes screw and also a worm screw. Its rotation leads to Supply silo components to the pyrolysis combustion chamber. The screw is made of mechanically welded materials. It consists of a tube at the ends of which two ends are welded. The screw must be turned along its entire length so that the outer profile is cylindrical and properly fits within the inner diameter of the sheath. Figure 3.6

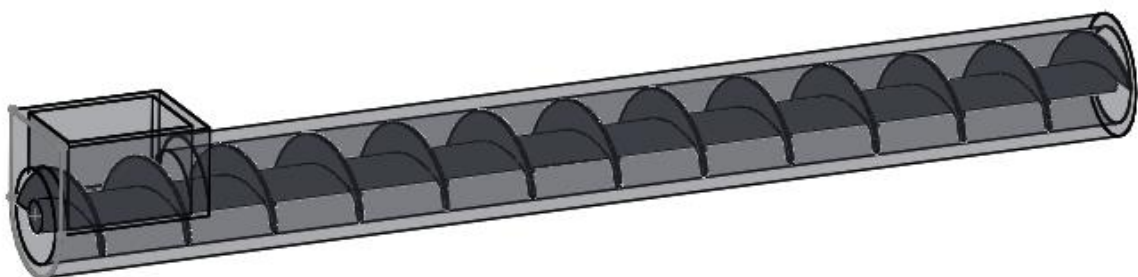


Figure 3.6. Worm screw driving.

3.7.5. Electric motor

An electric motor is a device that allows electrical energy to be converted into...Work or mechanical energy. The shape of the current, its voltage potential and its density will be the first constraints to determine the engine selection. Motor operating current sources are often of three types: direct current, single-phase alternating current, and three-phase alternating current. When you can count on it Powerful multi-voltage alternative distribution network, all solutions it may be taken into account; Technological advancement makes it possible to switch easily alternating current and converting it to direct current. Figure 3.7

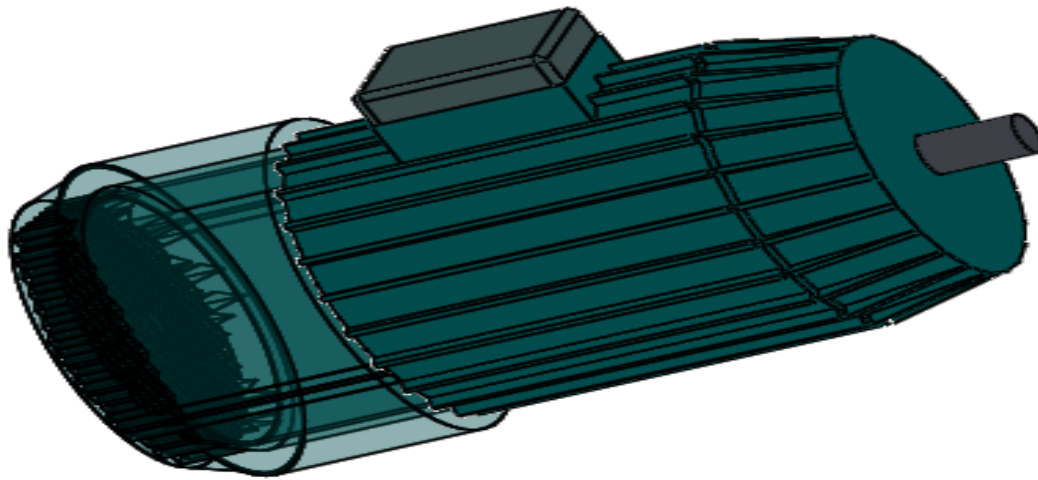


Figure 3.7. Electric motor.

3.7.6. Combustion body insulation system

Figure 3.8, the combustion chamber consists of a cylinder containing the heat exchanger and the bottom cover, as shown in Figure 3.5, is the body most exposed to heat. Material selection is essential to reduce heat loss. Since this part it is extracted from used Pyrolysis, and its properties are well known.

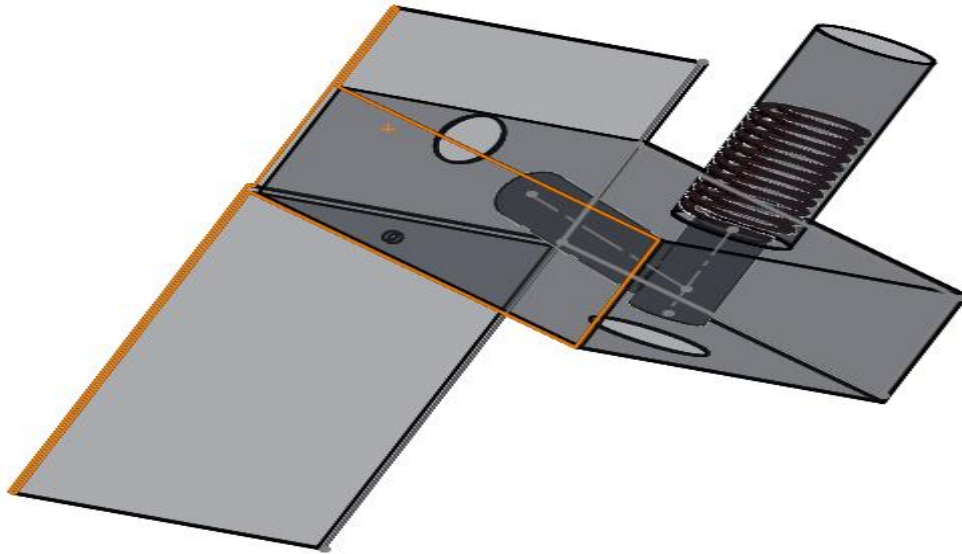


Figure 3.8. Combustion chamber.

3.7.7. The CNC frame (the frame)

This part will carry all the elements of the machine.

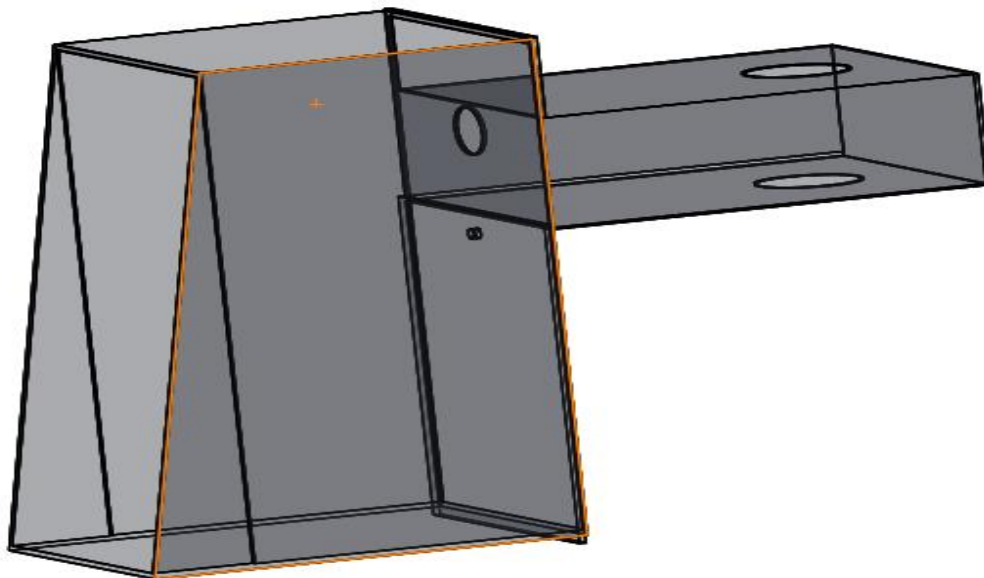


Figure 3.9. The frame.

3.7.8. Final assembly of pyrolysis machine

In this step, we collect the components of the pyrolysis machine A pyrolysis machine for hydrogen production includes several key components: Raw Material Preparation System: Prepares feed material through shredding, drying, and ensuring uniform size.

Chapter 3 Design of Pyrolysis machine of hydrogen production

Pyrolysis Reactor: Heats the material to high temperatures (400-450°C) in the absence of oxygen for Pyrolysis, it also produces ash and is loaded into large bags in the form of cubes.
Condenser System: Cools pyrolysis gases to form liquid pyrolysis oil and other vapors.
Gas Purification and Cleaning System: Cleans the syn gas by removing impurities.
Gas Separation Unit: Separates hydrogen from other gases in the syn gas mixture.
Hydrogen Storage and Distribution System: Stores and prepares purified hydrogen for distribution.

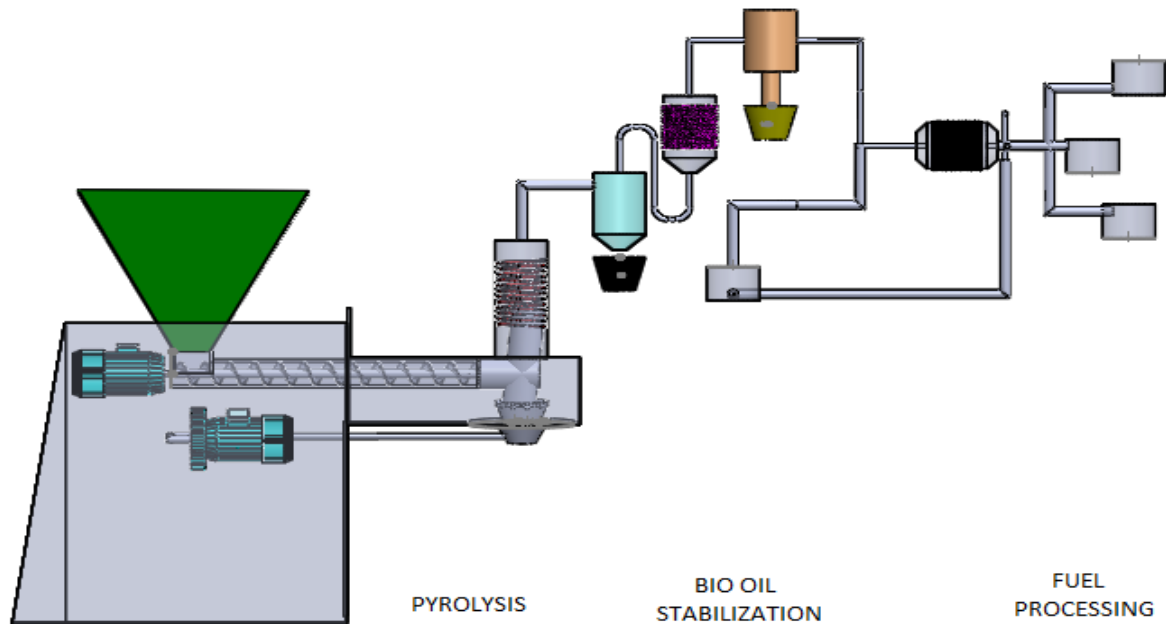


Figure 3.10. Converting biomass into bio fuel using Pyrolysis.

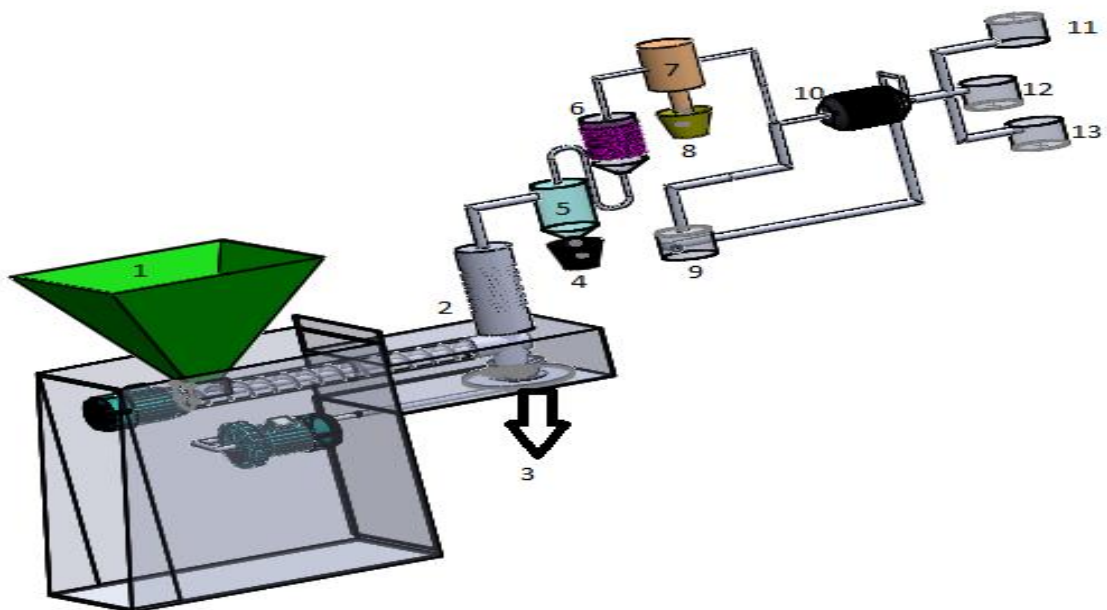


Figure 3.11. The Pyrolysis assembly

1-Pretreatment of Biomass	2-Pyrolysis Reactor	3- ASH PIPE
4- Bio-char	5- Cyclone	6- Condenser
7- Quencher	8- Bio-oil	9- H2
10- separation membrane	11- Gasoline	12- Diesel
13- Get fuel		

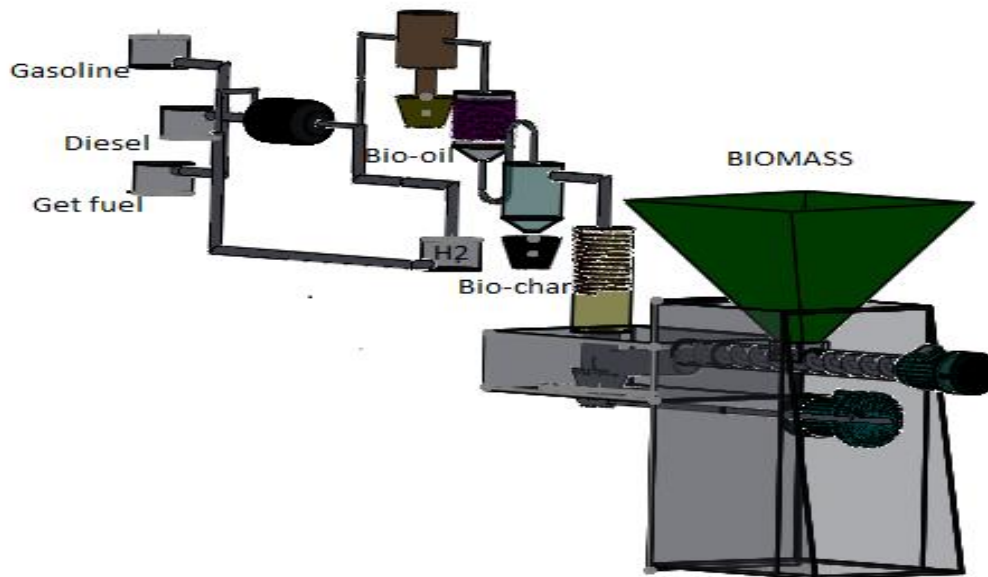


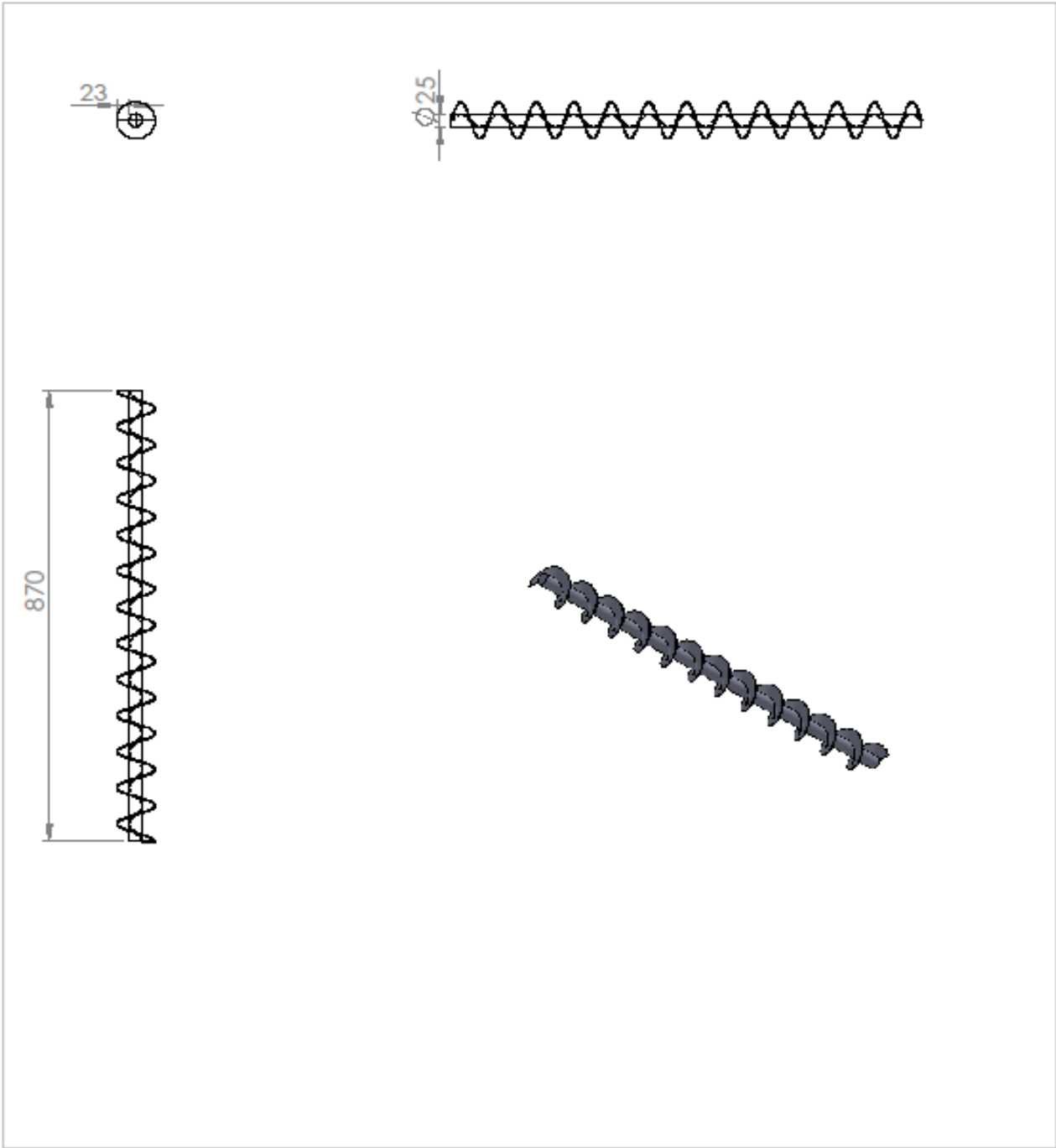
Figure 3.12. Final form of the Pyrolysis machine

3.8. Definition drawing Definition

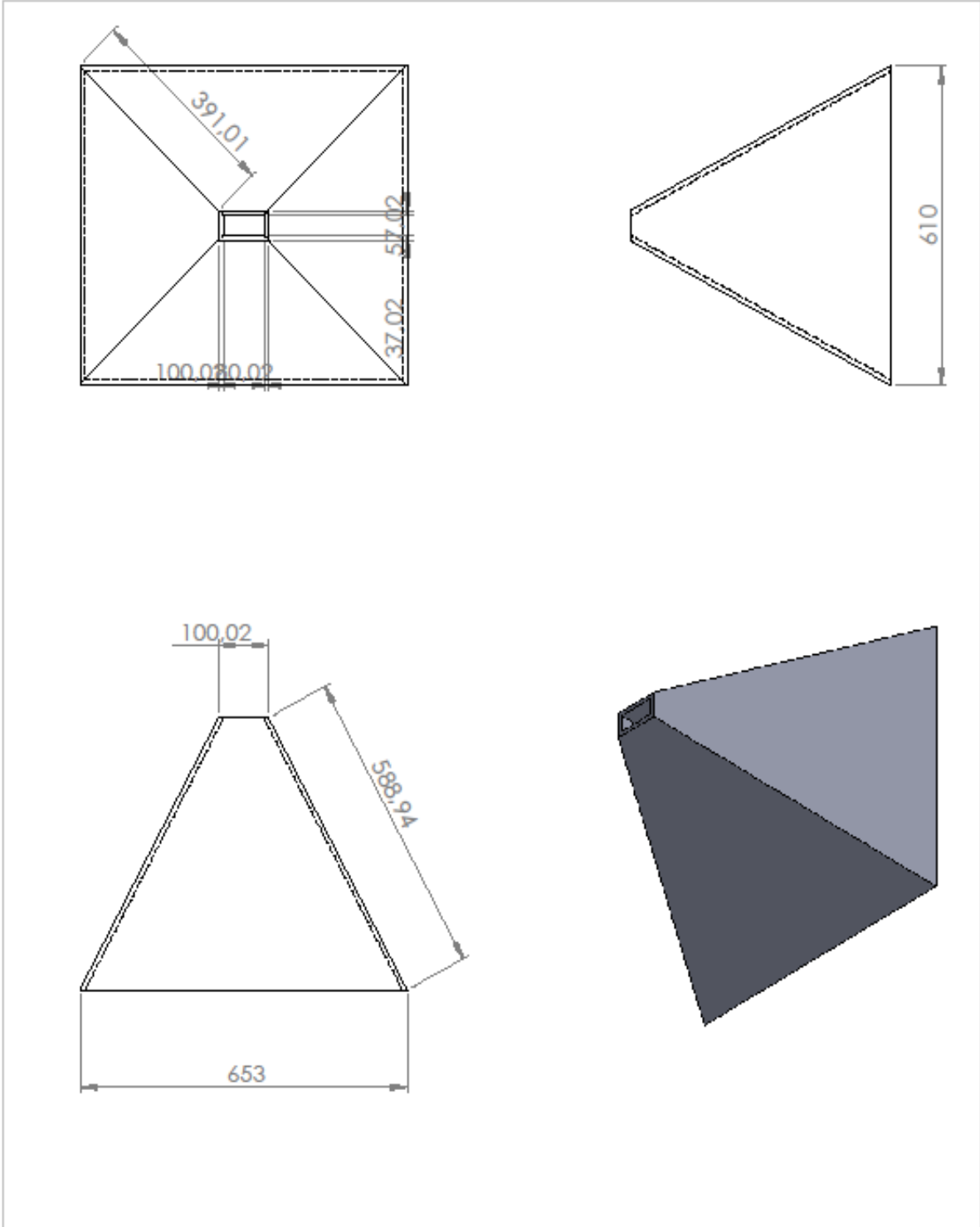
In industrial drawing, the definition drawing represents a part or part of an object projected on a plan with all its details such as dimensions in standardized dimensions and machining. It is also called a detail plan as opposed to the overall plan or overall drawing. Views: The number of views varies depending on the complexity of the piece represented. One view (or even two) for a cylindrical part, generally three views for a prismatic part. The front view is chosen based on its representativeness. All views must allow a complete understanding of the piece, so it is sometimes necessary to add details, perspectives and partial sections. The rating: It is essential and inseparable from the drawing. It defines the dimensions, shapes, surfaces and indicates their level of quality. We cannot forget to take into account the tolerance which is linked to the fact that it is inevitable to have manufacturing inaccuracies, imperfections, operating failures, etc. Tolerance allows the system (mechanics, IT, etc.) to continue to

Chapter 3 Design of Pyrolysis machine of hydrogen production

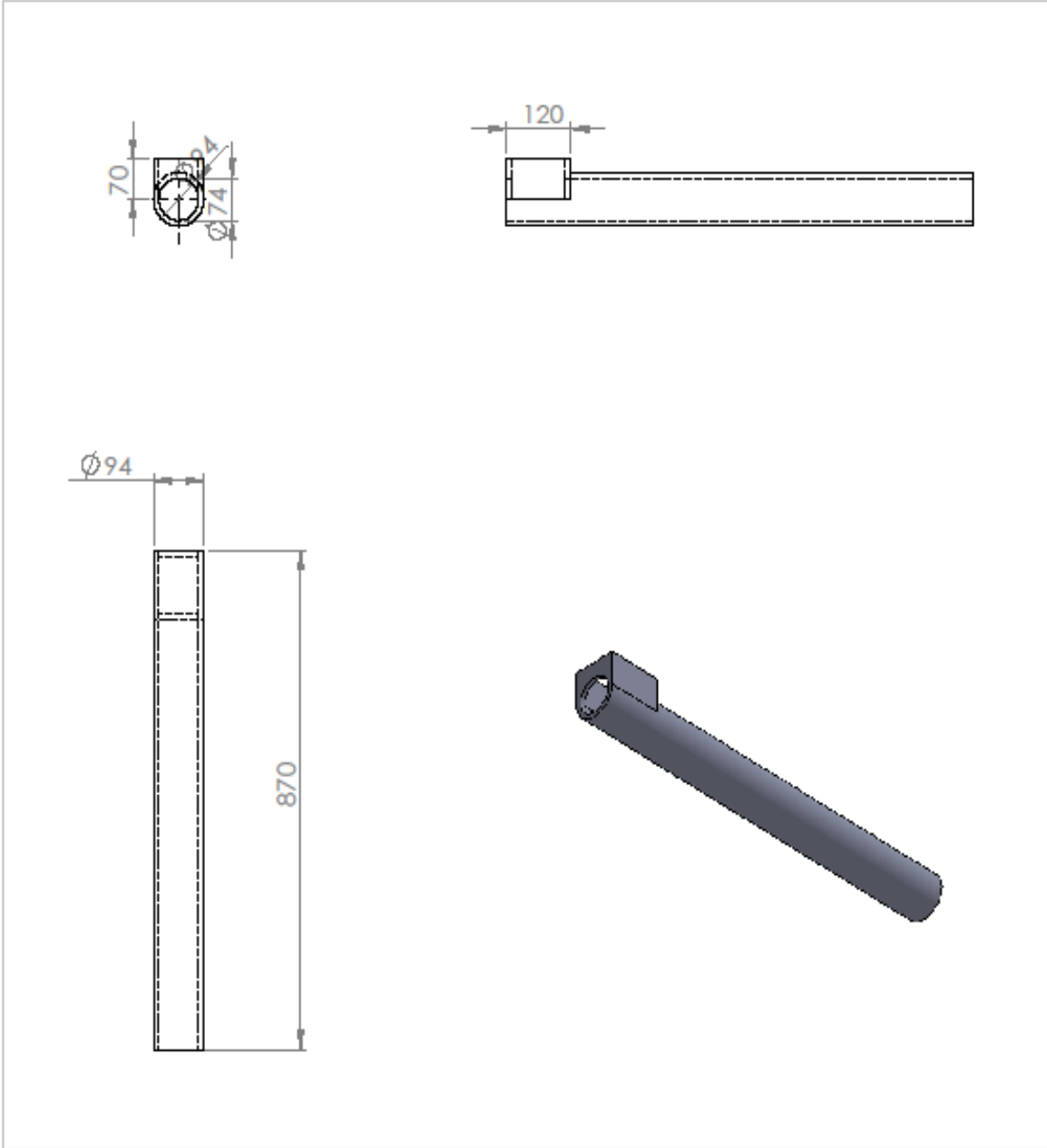
perform its function, either by setting the acceptable deviation (when it comes to manufacturing for example), or by designing a system taking into account the future deviations (failures). To clearly clarify the vision of the different parts of the machine, we have made every effort to make a definition drawing of each of these elements; you will find it in the appendix [35].



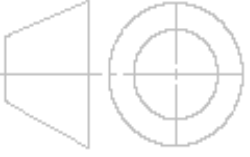
Hassiba Benbouali University of Chlef		
MESO15	Modeling and simulation in mechanics	
SCALE:1/1	Endless screw	souad ouadah tsabet
		Year2023/2024

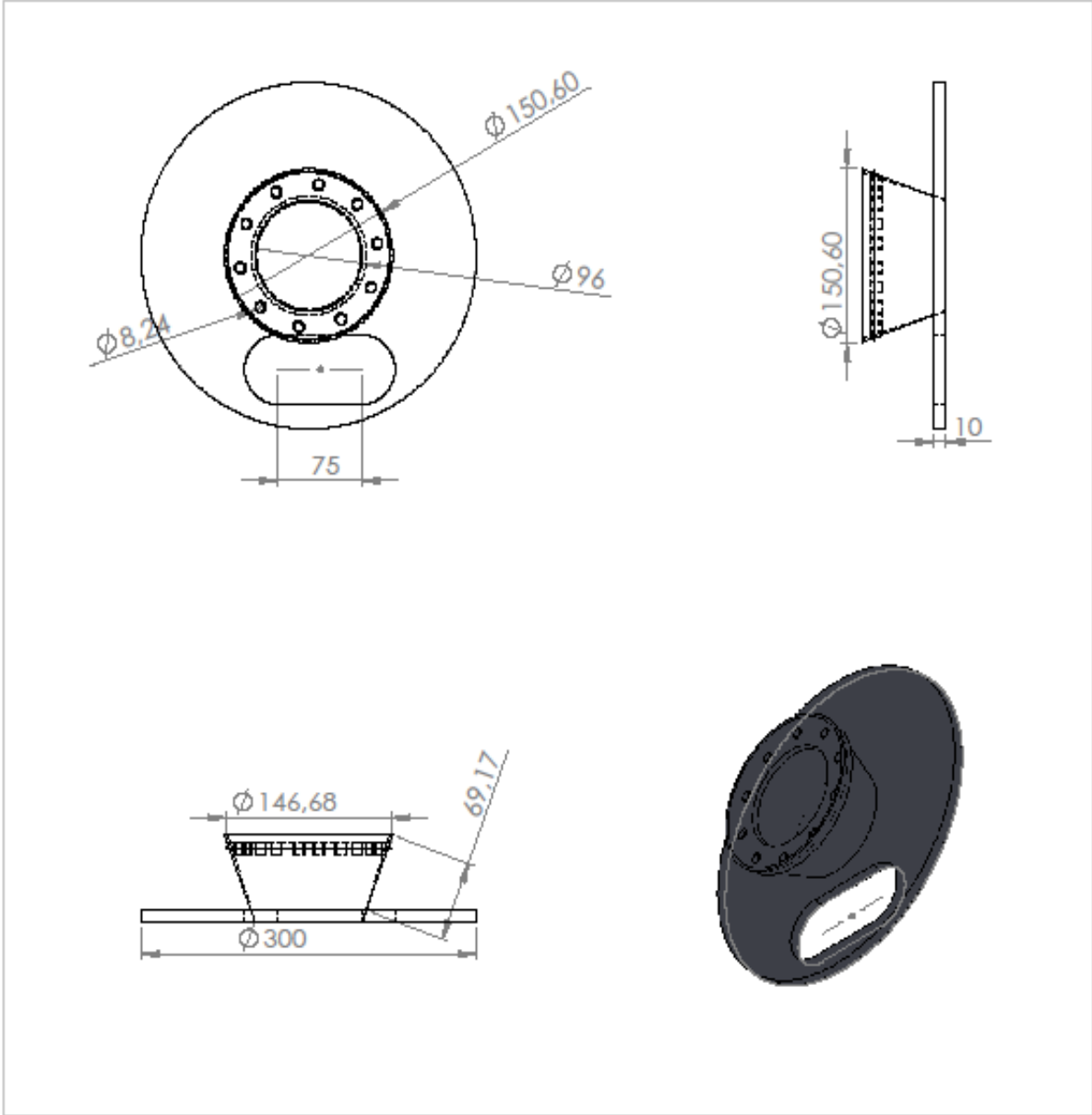


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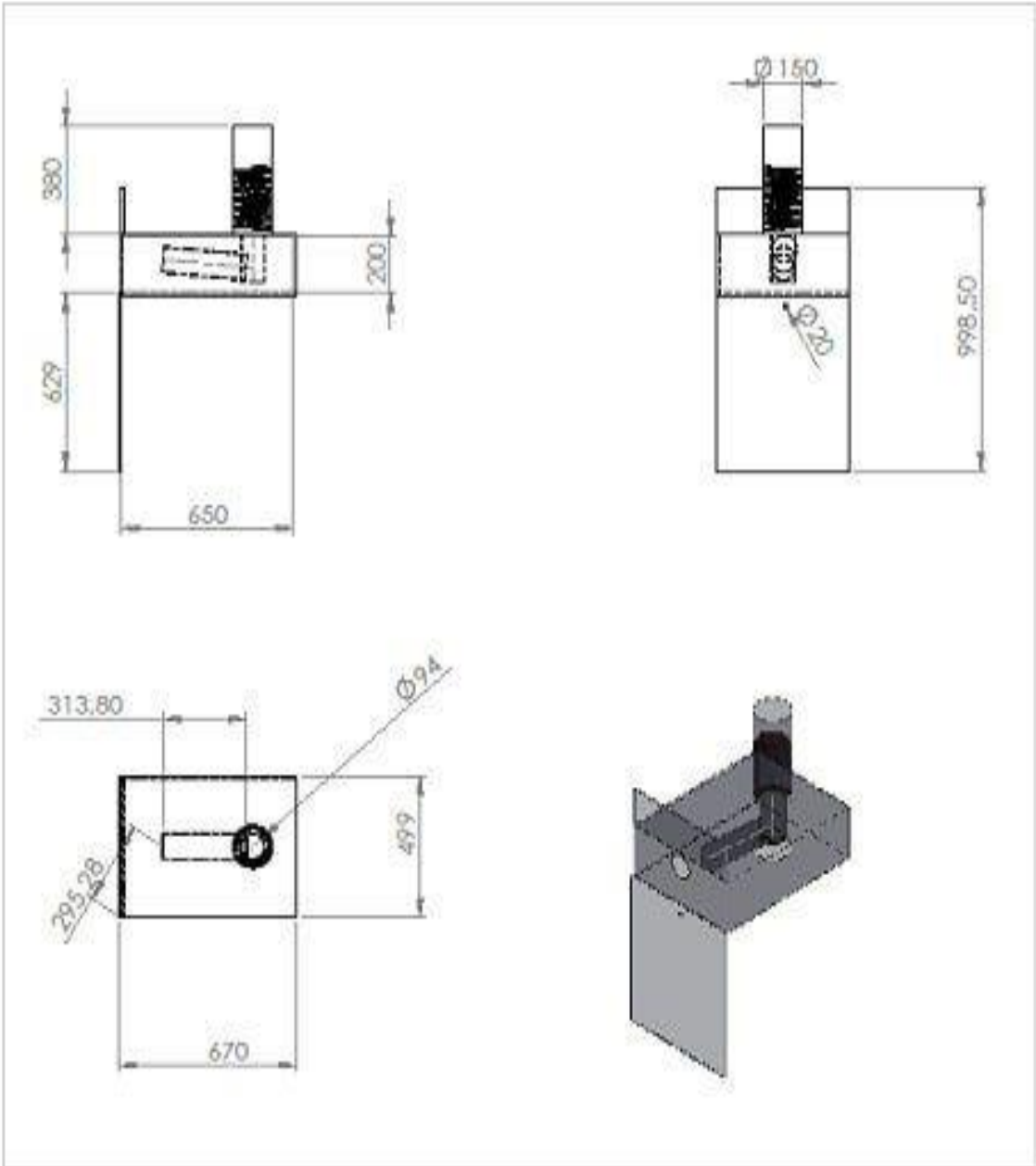
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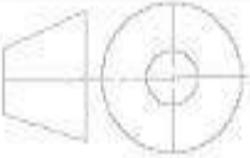


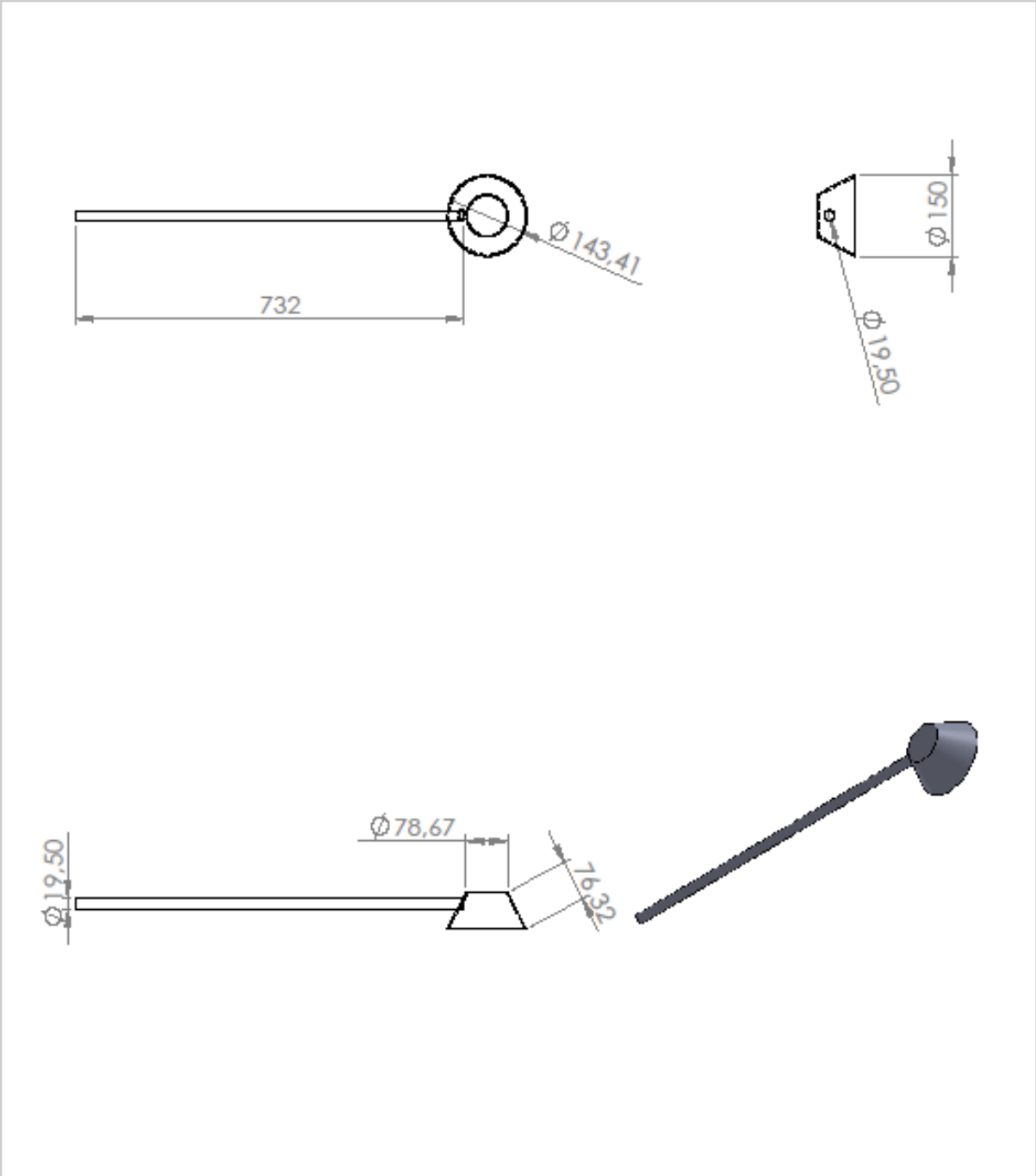
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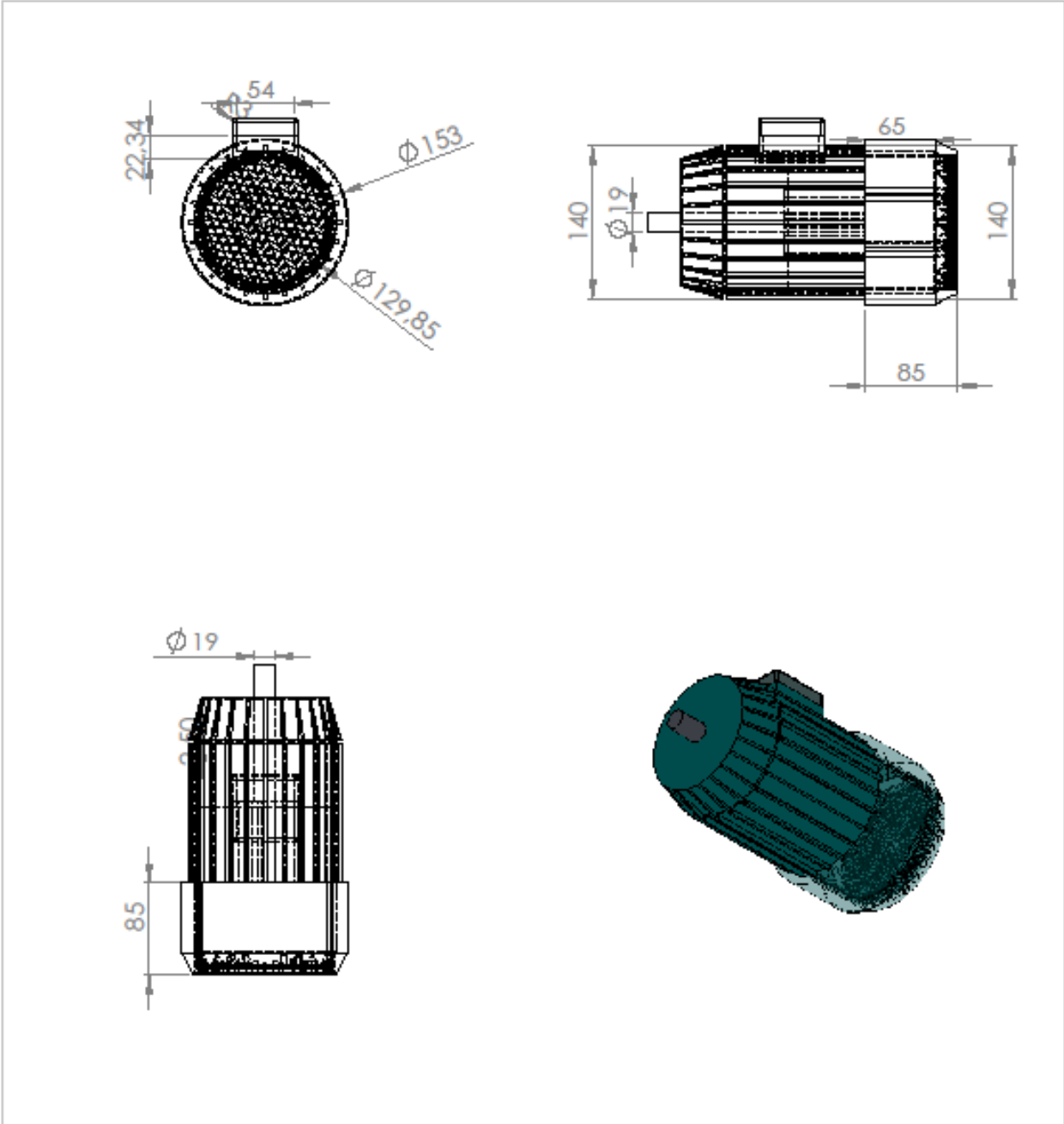


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MESO15	Modeling and simulation in mechanics	
SCALE:1/1		
	Combustion body insulation system	souad Ouadah Tsabet
		Year2023/2024



Hassiba Benbouali University of Chlef		
MESO15	Modeling and simulation in mechanics	
SCALE:1/10	Air line	souad ouadah tsabet
		Year2023/2024

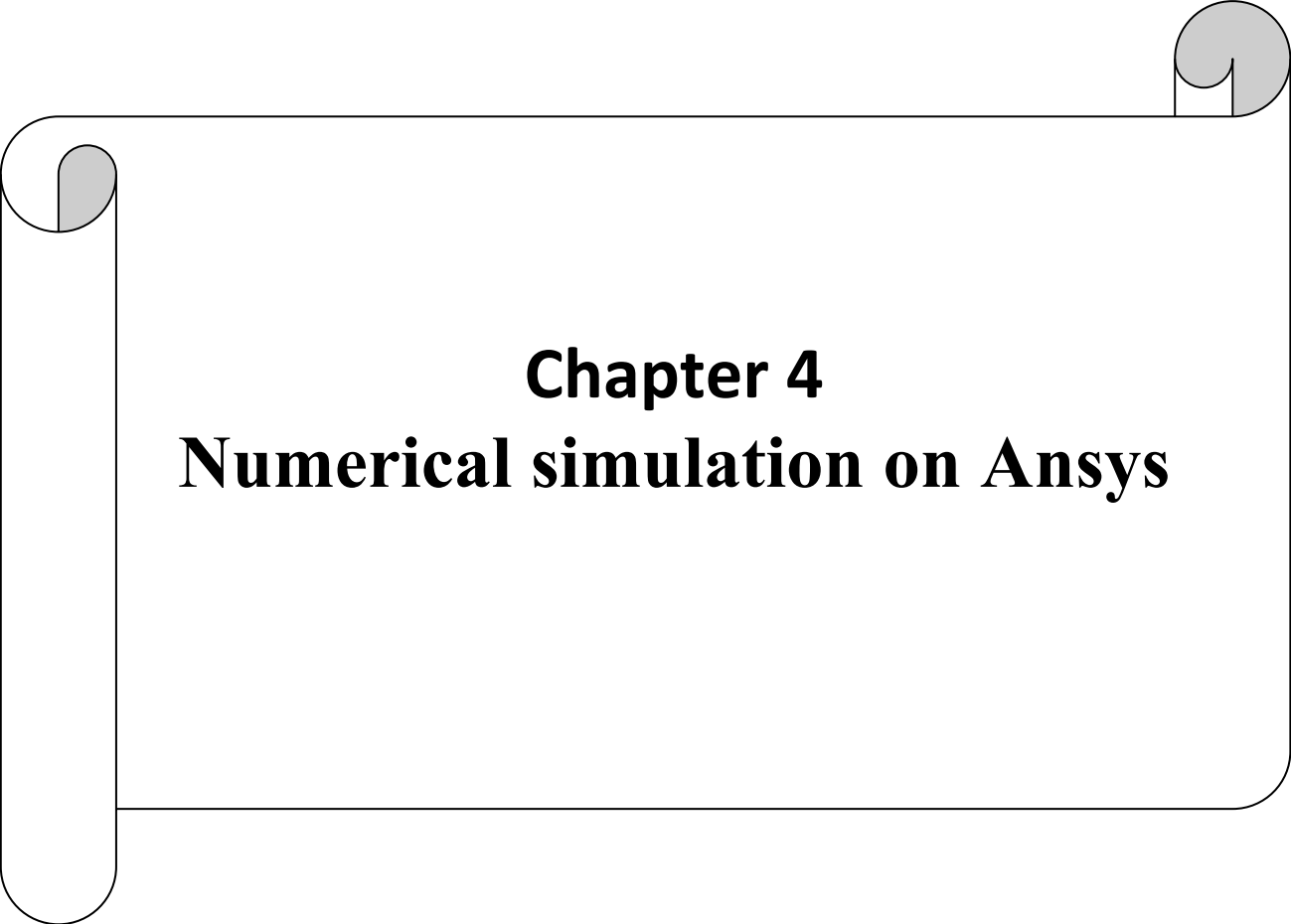


Hassiba benbouali university of chlef

MESO15	Modeling and simulation in mechanics	
SCALE:1/5	Electric moto	souad ouadah tsabet
		Year2023/2024

3.9. Conclusion

In this chapter we made the different parts constituting our machine using SolidWorks software so we explained the usefulness of each of these parts and checked the overall structure of the machine, and then we assembled the parts to get the final shape of the machine.



Chapter 4
Numerical simulation on Ansys

4.1 Introduction

A structural analysis is used to predict the behaviour of a medium (solid or fluid) Subjected to conditions imposed by the external environment (force, displacement, thermal-magnetic flow, etc.).

The aim of a structural analysis is to determine the stresses and strains of a system or component to which a load is applied, based on the de- This prediction is based on the satisfaction of a few fundamental equations some fundamental equations (mechanical equilibrium equation, heat equation, behaviour law...).

The ANSYS software, in the ANSYS Mechanical or Metaphysics versions, enables a range of structural analyses. Structural analysis, to which must be added thermal loading analysis of the structure's inherent responses (buckling and inherent resonance modes in particular). [36]

4.2 Analysis methodology based on finite element theory

1. Problem Definition

- Clearly define the physical problem, including the geometry, material properties, boundary conditions, and external forces.
- Specify the objectives of the analysis (e.g., stress distribution, deformation, and thermal analysis).

2. Geometric Modelling

- Create a detailed geometric model of the structure or domain to be analyzed.
- Simplify the model if necessary to reduce computational cost while maintaining essential features.

3. Discretization (Meshing)

- Divide the geometric model into smaller, finite elements (meshing).
- Choose appropriate element types (e.g., 1D line elements, 2D triangular or quadrilateral elements, 3D tetrahedral or hexahedral elements).
- Ensure mesh quality by checking element aspect ratios, skewness, and refinement in critical regions.

4. Boundary Conditions and Load Application

- Apply boundary conditions (e.g., fixed supports, symmetry conditions) to the model.

- Apply external loads (e.g., forces, pressures, thermal loads) according to the problem definition.

- Ensure correct application to avoid unrealistic or inaccurate results.

5. Solution of System Equations

- Solve the system of equations resulting from the finite element formulation.

- Use appropriate numerical methods (e.g., direct solvers like Gaussian elimination, iterative solvers like conjugate gradient methods) depending on the problem size and complexity.

6. Documentation and Reporting

- Document the entire analysis process, including problem definition, assumptions, modelling steps, and results.

- Prepare a comprehensive report detailing findings, conclusions, and recommendations. [38]

4.3. Modelling a biomass boiler with ANSYS FLUENT 18.2

4.3.1. Procedure

Create a new Fluid Mechanics (Fluent) project in WorkBench.

Import the geometry from the CAO software used (SOLIDWORKS).

Generate a mesh using the meshing tool.

Click on Edit in the project configuration section.

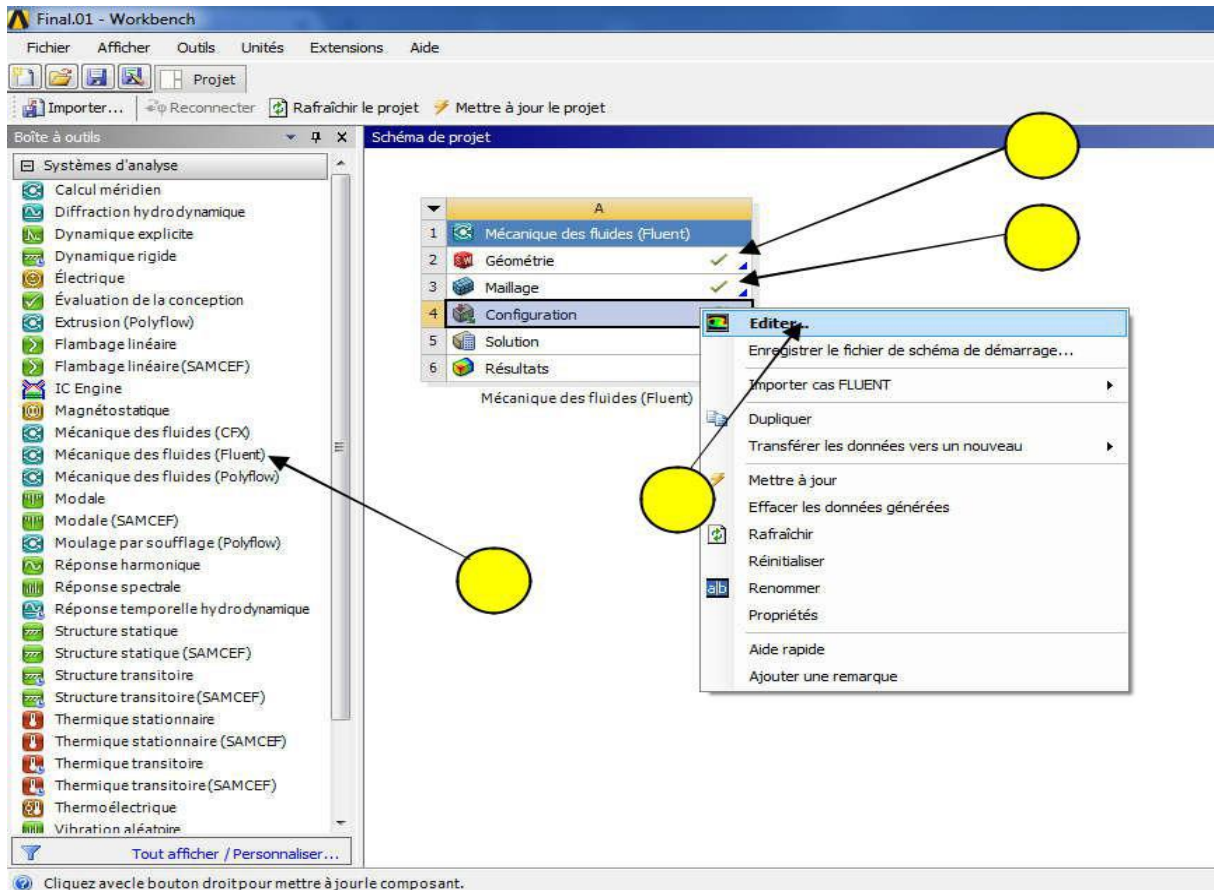


Figure 4.1. Main project window (ANSYS WORKBENCH).

In the General menu of the ANSYS FLUENT main window:

In the Solver section, make sure the following choices are checked: Type:

Pressure-Based, Velocity Formulation: Absolute, and Time: Steady.

In the Gravity section, select the gravity acceleration along an axis according to the geometric model.

Click on Units to define the units to be used (Si, CGs, British).

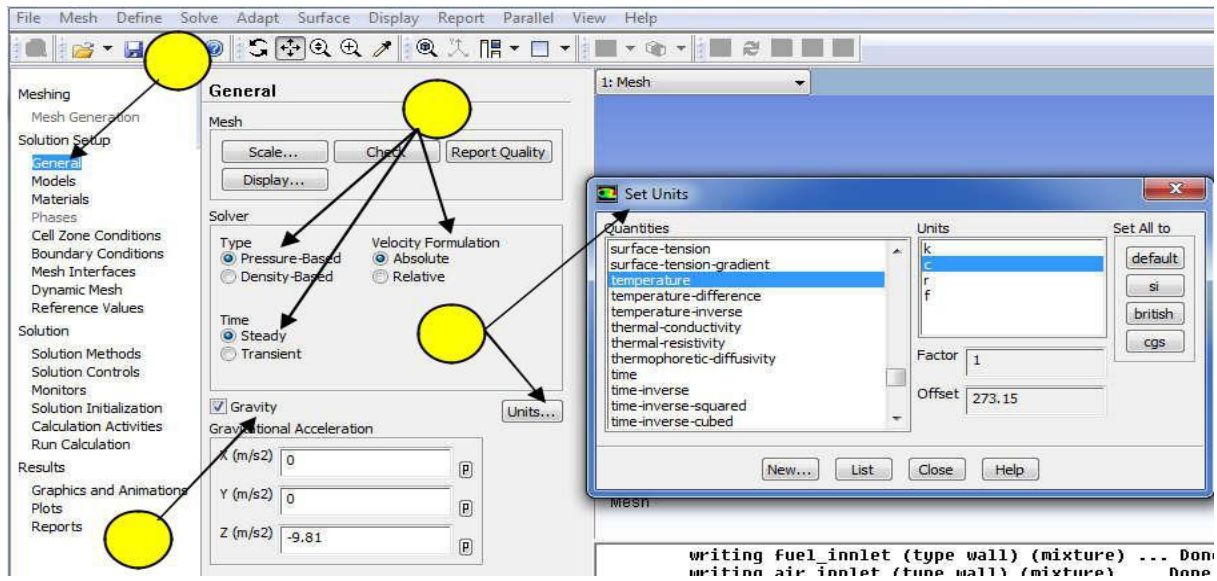


Figure 4.2. ANSYS FLUENT main window.

In the Models menu of the ANSYS FLUENT main window:

Activate the energy model.

In viscous, select the k-epsilon standard model, Standard Wall function.

In radiation, select the P1 model.

In Species, select the non-premixed combustion model.

Activate the discrete-phase model.

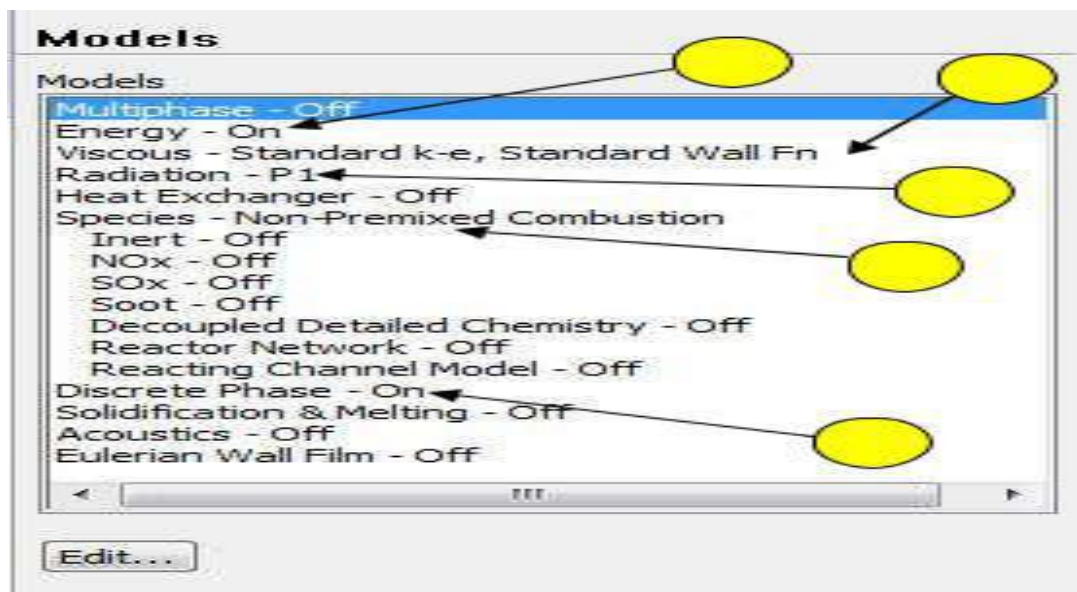


Figure 4.3. Model menu In ANSYS FLUENT

Species and Non-Premixed Combustion Make sure the following choices are checked: In state relations:

Chemical Equilibrium, Energy Treatment: Non-Adiabatic. Click on the coal calculator and define the chemical composition of the biomass. In the Table sub-section, select PDF options. Inlet diffusion and beta in probability density function. Finally, click on Calculate PDF Table.

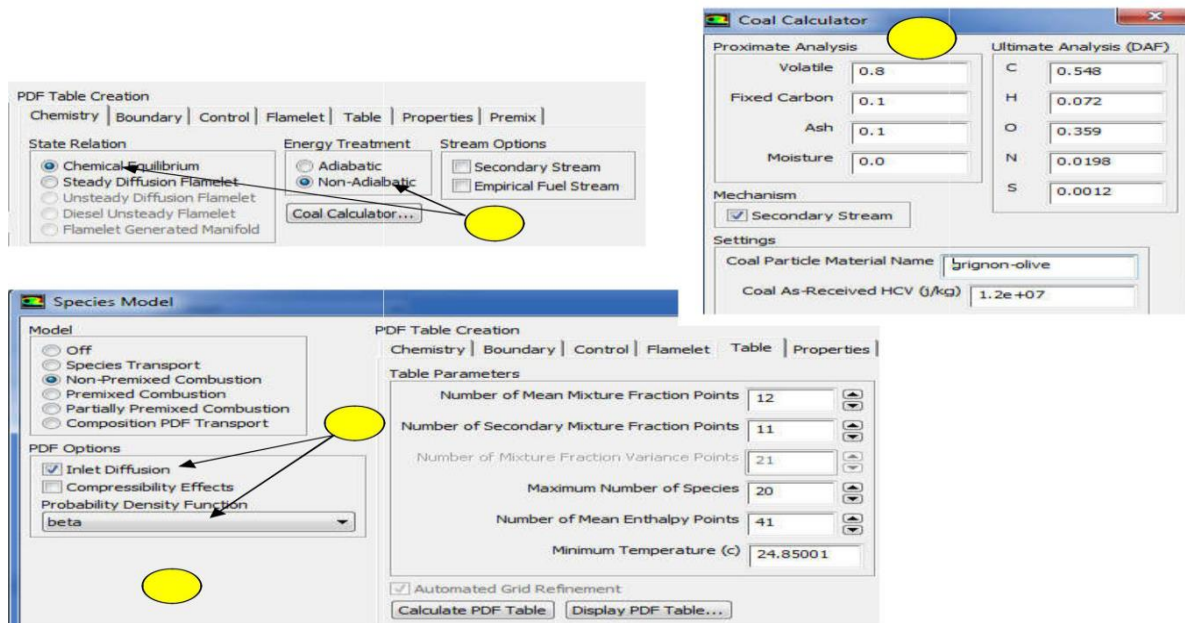


Figure 4.4. Windows of the Non-Premixed Combustion model.

In the Discrete Phase part:

- Click on objections, choose Injection Type, surface, Release from surfaces: fuel-Inlet, Particle Type: Combusting, Material olive pomade, Devolatilizing Stream Secondary ET Char Stream Primary.

In Physical Models choose Particle Radiation Interaction and Pressure gradient Force

In Drag Parameters choose Spherical.

In Turbulent Dispersion check Discrete Random Walk Model.

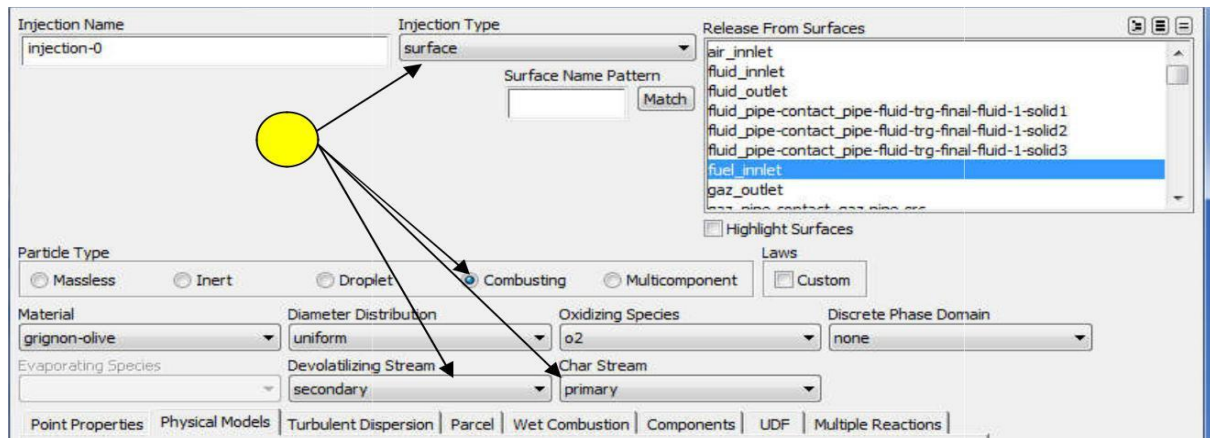


Figure 4.5. Discrete Phase model windows.

4.3.2. Results

ANSYS Fluent allows us to retrieve simulation results either as an Excel file or in graphical form.

Excel file or in graphical form, but as the geometry is complex, the Excel file is not to properly interpret these results.

To retrieve the results in graphical form, launch the CFD-POST module in WORKBENCH. CFD-POST module.

The figure below shows the temperature distribution in the combustion chamber.

The biomass injection system used results in a non-homogeneous temperature distribution.

Temperature distribution.

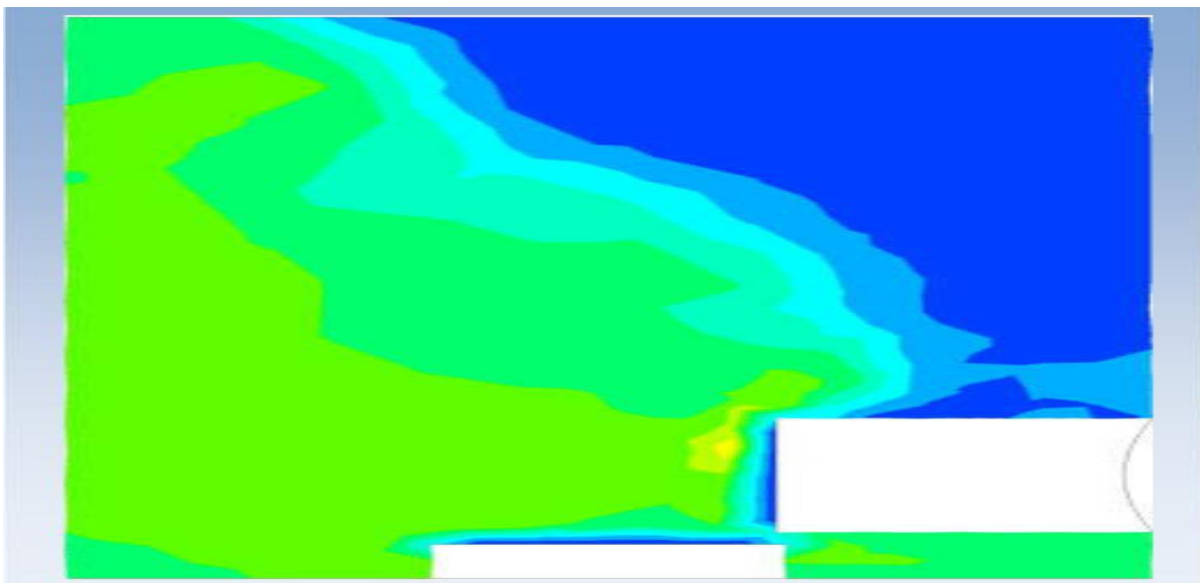


Figure 4.6. Temperature distribution on a median plane.

Figure 4.7 shows the temperature distribution in pyrolysis, the CFD-POST module.

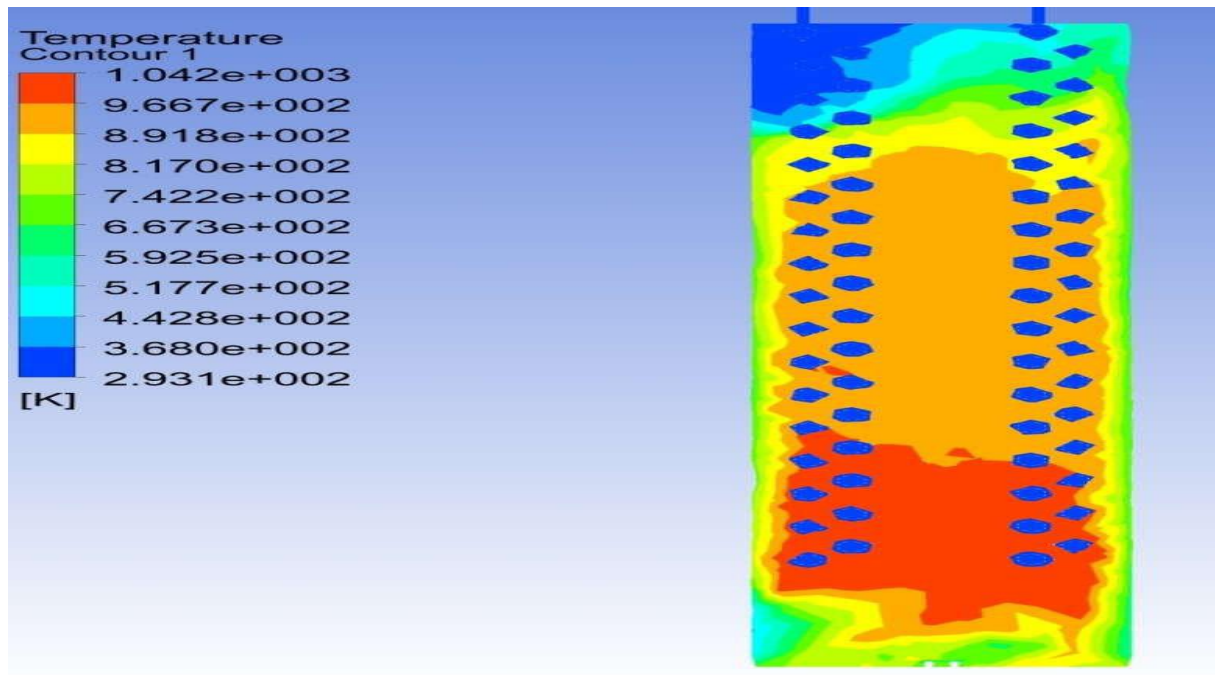


Figure 4.7. Temperature distribution in the combustion chamber.

The exchange surface provided by the coil is not sufficient to reach the design temperature design temperature (80°C).

The difference between the design temperature and the temperature resulting from the is due to heat losses not taken into account in the preliminary fuel flow calculation.

The heat losses are mainly stack losses (107°C at the stack outlet), casing losses to the outside environment and biomass combustion efficiency. biomass.

In this simulation, we have omitted to mention the pressure and velocity distribution, as biomass combustion does not generate any heat loss. biomass combustion does not generate high pressures. The flow velocity is

The flow velocity is also small, due to the size of the pyrolysis carried out in this work.

Possible avenues for increasing efficiency include:

- Using the exhaust gases to preheat the inlet air, thereby

increase combustion efficiency and thus pyrolysis efficiency.

- Use an underfeed stoker-type biomass feed system.

(stokers, which has an impact on the homogeneity of temperature distribution.

temperature distribution.

- Adding obstacles in the coil to guide the combustion gases, which enables for better heat exchange.

4.4. Conclusion

Numerical simulation on ANSYS offers a powerful and versatile platform for analyzing and solving complex engineering problems. ANSYS can be used to run a variety of simulations, such as structural analysis, fluid dynamics, heat transfer and electromagnetism. Thanks to its advanced modeling capabilities and detailed analysis tools, ANSYS helps engineers optimize designs, reduce prototyping costs and improve product performance and safety.

Using ANSYS for numerical simulation results in a significant improvement in efficiency and accuracy in product development, enabling technical challenges to be overcome with greater confidence and speed.



General Conclusion

GENERAL CONCLUSION

General Conclusion

The transition to a hydrogen economy represents an essential pivot towards cleaner and more sustainable energy. This project explored the different aspects of the hydrogen value chain, with a particular focus on pyrolysis production. By examining the production methods, transportation, storage and distribution of hydrogen, we have identified the key challenges and opportunities facing this growing field. Pyrolysis, as a method of producing hydrogen, offers significant advantages, particularly in terms of reducing carbon emissions and using renewable biomass. An in-depth review of pyrolysis production systems has highlighted their potential and limitations, while highlighting the technological advances needed to improve their efficiency and profitability.

The functional analysis of the elements of a hydrogen pyrolysis machine, through tools such as the "Horned Beast", "Octopus", FAST and DAST diagrams, made it possible to detail the internal and external interactions of the components, thus facilitating an overall understanding and optimization of the design. The detailed design of the pyrolysis machine, presented in the third chapter, provides a clear roadmap for the development of an efficient and safe hydrogen production system. Technical specifications, material choices, and manufacturing and assembly processes have been rigorously defined to ensure compliance with safety and performance standards. Finally, numerical simulation via ANSYS offered crucial validation of the thermal, structural and dynamic aspects of the machine. Simulation results helped identify optimization opportunities and ensure the final design meets operational and safety requirements. In conclusion, this study shows that, although significant challenges remain, particularly in terms of costs and infrastructure, hydrogen, and in particular production by pyrolysis, constitutes a promising path for a sustainable energy transition. Technological innovations and research efforts will continue to play a key role in realizing this vision, making hydrogen a cornerstone of the clean energy of the future.



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