Hungarian University of Agriculture and Life Sciences.

(Szent István Campus)

Thesis.

Topic: - **Design and manufacturing of a Hatchet blade.**

BSc. Mechanical Engineering

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Institute/ Department: Institute of Technology.

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▪ Summary

This work was conducted during my internship at **Dendrit Mentor Kft. 1103 Budapest, Kazah u. 8, Hungary.** I utilized the company's resources and data to develop the project. I am grateful for the support and resources provided by Dendrit Mentor Kft, which enabled the successful completion of this research.

The purpose of this thesis is to manufacture a hatchet blade for composting machine which is cheaper than the conventional blade without compromising its functionality. Strong and durable blades is the necessity of composting machine which are efficient to cut down the organic material. Because of high standards of manufacturing and high-carbon materials, conventional blades are expensive.

The aim of this study is to develop an alternative blade which fulfils all the requirements of hatchet blade at a reduced cost. Traditional blade was made up of high-carbon steel which contributes high manufacturing cost. After a lot of material research, we have selected S235 steel on the balance of its hardness, wear resistance and lower cost to avoid the expensive manufacturing techniques.

The research started with the analysis of an existing blade design, materials and manufacturing techniques which are useful in composting applications. In this study CAD software was used to create a new blade model appropriate for the composting applications. To find out the most cost-effective method, we have evaluated all the manufacturing method like cutting, milling, bending and CNC machining then after selected the most cost-effective approach for the manufacturing of hatchet blade considering its functionality and structural integrity.

After a comprehensive cost analysis, it was clear that the newly designed blade costs significant less to manufacture than the original blade. This study has successfully created a cheap and best alternative to traditional composting blades, which is a practical solution for the composting industry. Other suitable materials and advanced manufacturing techniques can be found in future research for the improvement, durability, blade's strength and cost efficiency.

▪ Introduction

In farming and animal processing, turning waste into compost fertilizers is very important. A key tool for this job is the hatchet blade, which helps break down and dry out organic materials from animals and plants. This thesis is about design and making of a specific hatchet blade made by the Japanese company KOHSIN. This blade is used in the KSN machine (dryer & semi-composter) to dry extracts and create compost fertilizers.

Figure 1: Hatchet Blade (own pic...)

Figure 2: KSN Machine

KOHSIN'S hatchet blade is very important for the KSN, which involves drying and processing organic materials. Its unique shape and function allow it to handle the tough demands of this job, making it durable and efficient. Our main goal is to study the current KOHSIN hatchet blade and suggest improvements to make it cheaper and more effective.

To understand what the blade needs to do, we must consider the KSN machine. The blade must be strong and sharp, able to chop and dry organic materials and turn it into small pieces effectively. It also needs to resist wear and rust to last longer in the wet and acidic conditions typical of composting.

Choosing the right material for the blade is very important. Different materials, like high-carbon steels and special alloys, will be looked at to see which can do the job well while keeping costs down. Modern manufacturing techniques, such as precise forging, heat treatment, and surface coating, will also be explored to improve the blade's qualities and production efficiency.

Using the provided shape of the KOHSIN hatchet blade, computer-aided design (CAD) and finite element analysis (FEA) tools will help design the new versions of the blade[1]. This tool will allow us to see how well it cuts.

The goal of this research is to create a hatchet blade that is affordable, efficient, and durable. By improving on KOHSIN's existing design, the new blade will provide a more economical solution for the composting industry, helping with sustainable waste management and farming practices. The results of this study will be useful for both academic research and practical applications, encouraging innovation in the design and making of specialized tools for agriculture and environmental sustainability

▪ Literature Review

a) Compositing in Agriculture

Composting is a controlled process where organic matter decomposes into a stable, nutrient-rich product called compost. Unlike natural decomposition, composting is enhanced by creating optimal conditions for microbes to thrive, turning waste into a valuable resource. This recycled product is rich in stabilized organic matter and carbon and is largely free of pathogens and weed seeds.

Compostable materials include crop residues from greenhouses, manure from cattle farms, agro-industrial processing leftovers, and unsold agricultural products. These materials are nutrient-rich and break down easily. For effective composting, it's important to mix these residues with bulking materials like pruning waste, wood chips, and straw. These additions help improve the compost's structure, allowing air to circulate and supporting the activity of aerobic microbes[2].

Figure 3: Compost life cycle (wikipi.)

The resulting compost can be applied to soil to improve fertility, restore degraded lands, suppress plant diseases, sequester carbon, and reduce the need for chemical fertilizers and pesticides. This approach not only cuts production costs but also lessens the environmental impact of farming. Additionally, compost has various uses, such as in nursery cultivation, mulching, landscaping, managing public parks, and rehabilitating damaged lands.

Composting is a sustainable alternative to landfilling, reducing waste volumes and eliminating harmful organisms. It also supports the circular economy by recycling agricultural biomass. This aligns with broader environmental goals, such as those of the European Union, which aims to significantly reduce the amount of organic waste sent to landfills.[3]

b) Importance of turning organic waste into compost fertilizers

In a lot of ways, converting organic waste into compost fertilizers is more important than efficient waste management– it can facilitate environmental health and the maximal productivity of agriculture while supporting sustainability. This process helps us to survive longer in balance with our planet.[4]

Organic waste, if not properly managed in landfills, can lead to environmental deterioration. The result is methane, a greenhouse gas 30 times as potent for climate change warming as CO_2. In contrast, composting transforms it into a useful commodity when broken down into humus-material rich in nutrients. As a rich source of organic matter, the humus anyway improves soil structure by breaking up compacted soils and as an aid to water holding capacity of soil it combats soil erosion.

Figure 4: Organic compost

(https://lomi.com/blogs/news/benefits-of-composting)

On the other hand, composting does not only cut down on negative externalities from organic waste, but also creates something that is good for environment policy. Healthy soil is one of the most important elements to thriving ecosystems. Productive soil is bursting with beneficial microbes and mycorrhizal fungi that connect plants in a strong network of communication. This just means that rich soil supports all living organisms. Unhealthy, or barren, soil, on the other hand, is a symptom of failing natural systems. Barren soil cannot hold water or nutrients, making erosion more likely and dry periods without rain that much more destructive. Adding pre-compost will reduce soil erosion, which improves soil health. One of the major benefits of compost is that it can reintroduce nutrients, microbes, and other beneficial composting organisms into the soil, healing these systems over time. As we know that Soil is the foundation of the mutually beneficial relationship between mycorrhizal fungi and plant roots. Their relationship results in larger, healthier plants and increased resilience against environmental disturbance.[5]

One of the several ways composting benefits the environment is by diverting food waste away from landfills. Organic refuse will take far longer than inert garbage to break down in a landfill. First, the lack of oxygen in landfills creates anaerobic conditions, which prevent helpful microorganisms from decomposing garbage. Anaerobic digestion of food waste results in the production of methane gas, a potent greenhouse gas that can trap 25 times more heat than carbon dioxide. Among the many human activities that contribute to the release of methane into the atmosphere, the anaerobic degradation of organic materials ranks third among the most widespread.[6]

I. Boosting Soil Fertility and Crop Yields

Compost fertilizers are a magic potion for agriculture. In addition, unlike synthetic fertilizers that can ultimately sideline your soil quality, compost gives a slow and steady. This slow release of nutrition helps the roots to grow deeply and become strong for a healthier plant. Compost also supplies a microbial feast for soil biology, increasing the biodiversity and resilience of the soil which in turn benefits crops. They them help to break down organic matter and cycle nutrients, making N more available to plants and reducing the need for nasty chemical fertilizers.[7]

Earth loses an astounding 30 percent of its harvested food. Composting alone may divert as much as one hundred percent of organic waste, which is in addition to the obvious goal of minimizing food waste. Instead of being broken down and returned to the soil, organic waste is being sent to landfills, even though they contain vital nutrients.[8]
The displacement of native species is a direct result of the massive landfills that are displacing natural ecosystems and habitats. There have been documented leaks that have caused biological harm in the region, even though all landfills are required to have a protective plastic covering along the bottoms to avoid any potential leakage into the neighbouring ecosystems.[9]

II. Efficient Waste Management

There is simply a mountain of organic waste it produces daily. Composting is the perfect solution to help keep food waste out of landfills and put it to better use. This helps takes pressure off traditional waste management systems, and instead recycles the valuable nutrients back into the soil. The plant is an example of a circular economy, where waste is not wasted but treated as a resource.

The addition of compost to soil may enhance the soil's natural bacteria and nutrients, which is one advantage of using compost in gardening. Even for those who are just getting their gardens off the ground, this may be a huge benefit. With time and a steady supply of compost fertilizer, you can build soil that is strong enough to sustain your fruit and vegetable crops. Artificial fertilizer isn't always necessary when using pre-compost since it contains many of the essential element's plants require. Producing synthetic fertilizer requires a lot of energy and results in the release of a lot of greenhouse gases[10].Overuse of artificial fertilizer increases the likelihood of nutrient runoff, which in turn increases the likelihood of a host of environmental concerns. Plants are better able to withstand pests and illnesses when they have a steady supply of organic matter, which also helps them grow taller and faster. [11]

III. Economic and Social Benefits

There are huge financial benefits from composting. Provides municipalities with cost savings on waste disposal for farmers, it means saving on expensive chemical fertilizers, reducing input costs and increasing their margins. In addition to that, it can generate local jobs in terms of production and sale of compost, which would further support the area economy. On a broader scale, healthier crops mean less need for chemical pesticides, which are costly and harmful to the environment.[12]

Among the many advantages of composting food scraps is the ability to identify exactly what kinds of food we are throwing away. We may easily modify our weekly supermarket buying if we put our wilted salad mix in the composter on a weekly basis. One of the best ways to save down on food shopping expenditure is to compost. Keeping tabs on what spoils and goes into the compost will help you identify the types of garbage you produce. Even without contributing to landfills, you may get a soil additive that is rich in nutrients.[13]

Figure 5: Fertilized soil

(https://www.weforum.org/stories/2023/01/5-ways-to-scale-regenerative-agriculture-davos23/)

c) KOHSIN Hatchet Blade and KSN Machine

I. Hatchet blade: This work aimed at development of C-type rotary hatchet blades to minimize the energy demand for tillage by optimizing the parameters which affect the cutting force of the hatchet (rotary) blades. Reduced draft demand, improved compost breakdown, and more effective inversion and compost mixing are obtained with rotary hatchet blades. Hatchet blades can be found in various shapes (L shape, C shape, J shape) and dimensions.

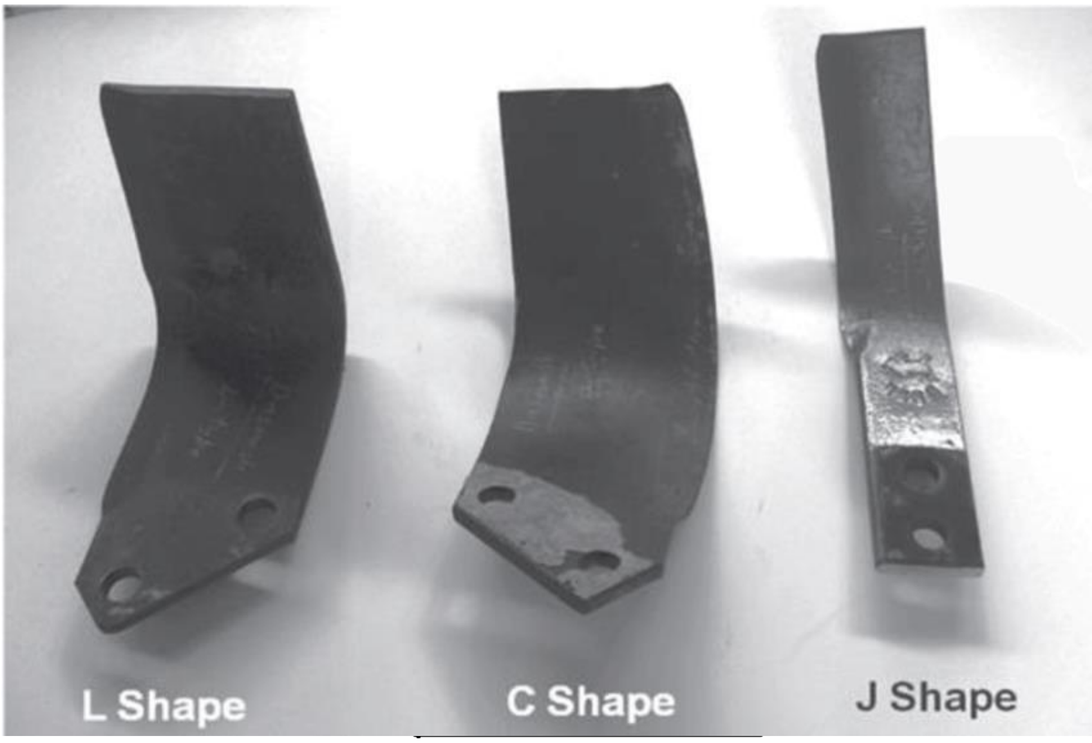

Figure 6: Hatchet blade types

There are several types of hatchet blades in different shapes and sizes (Fig 06) but here we are being specific about rotary hatchet blades. The best suited blade for our purpose is the C-type, it was fabricated using blade geometrical parameters matching to the minimum and optimum blade surface area per unit volume of compost turned and cutting angle based on the findings of computer programs. Specific work demand in different numbers of blades per flange, forward speed and rotor speed also guided evaluations of fabricated blades.
The C-type blade provides higher efficiency with higher compost turning and mixing volume and particular task demand than from other blades.[14]

II. KSN Machine: (Dryer and semi-composter) combine solar drying with semi-composting of organic waste. The KSN machine are being used here turns trash into semi-compost fertilizer. By use of continuous motion and water evaporation under solar heat, this machine displays great ability for cutting, twisting, and efficiently drying the raw materials. KSN also offers a seven times higher mixing capacity than conventional mixing. Through spinning and mixing, this machine greatly reduces the raw materials compaction. These days, KSN machines are becoming more and more used for numerous reasons.

Figure 7: KSN machines (Dryer and semi-composter)
https://www.kohshin-s.jp/product-en/ksn-type-fermentation-dryer/

These fall within active implements classifications. Within these machines, the power take-off (PTO) drive transfers power from the machine to the tiller. The shaft with blades, located at a 90° angle to the machine's direction of travel, rotates in the same direction as the forward motion. Turning and mixing is achieved as the shaft spins at a much quicker rate than the matching machine speed. Available machine power limits our ability to run the rotary tiller. Even a little percent increase in the efficiency of tillage equipment would result in a significant energy reduction. It would be considerably more cost-effective to raise the machine's production rate than by increasing the total number of machines arbitrarily. We can do that by reducing the power consumption by improving blade design.[15]

Rotary hatchet transfers energy into the compost to create some desired effect as cutting, breaking, inversion, or turning of compost. This process goes from a starting state to a different ultimate condition for composting. This is the heavy material handling activity and a main activity in preparation of compost is machine composting. composting is a process using a composting machine requires a lot of energy input. Therefore, even by a tiny percentage, improving the efficiency of composting techniques would save a lot of energy. Most of the compost-engaging instruments in use have been created by experience and creativity. Several natural benefits of machines, which provide power straight to the compost. The increase in energy requirement occurs when the chopping edge of the blade presses into the uncut compost material. Depending on the compost conditions, blade shape, and velocity ratio, the contact between the bottom of the blade and the uncut compost could produce extreme compost compaction and high-power consumption. The main cause of vibrations on the tiller blades is the reaction of compost. The proper design of the inter-related cutting and clearance angles of rotary tiler blades determines their successful performance. Throwing and mixing become increasingly crucial because the effective cutting angle increases from some minimum value, therefore influencing the power demands of the tiller and the amount of compost cut [16] Tillage tool geometry approach mathematically provides many advantages. One might exactly specify a desired shape in terms of a somewhat narrow collection of geometrical properties. Changing such a form begins to make sense when one changes these elements. Manufacturing of a given shape should be considerably easier as the geometrical information used in the design and visualization may be just transferred to a numerically controlled machine tool. The method enables a comprehensive examination of the influence of the geometrical elements on the energy requirements and final compost state. The rear surface of the blade rubbing against the uncut compost causes the energy demand to rise. The interference between the backside of the blade and the uncut compost depends on the compost conditions, blade shape and velocity ratio, therefore causing either severe compost compaction or high-power consumption. This is the primary source of vibrations, which the response generated by compost against the tiller blades.[17]

III. Wear of the Blade

The major cause of tool failure is worn on ages of blades; so, having knowledge of wear resistance is of great importance to engineers planning tools. Nevertheless, wear and their remedies have been the point of interest for researchers in the field of engineering design and manufacturing in this context it is important to know different form of wear and the factor that caused deterioration of metal due of use and inter dependency on wear resistance of material. To find optimal mixture of tool particles for extended life, many studies have been conducted to grasp the mechanism of wear and interaction of compost tool system factors on wear resistance. The most recent advancements in material science and coating technologies open new production techniques and improve the wear resistance of substrate material forming the main body of tool with sharp edges. With an eye on the current study's goals, literature has been reviewed to provide understanding of the many wear resistant’s treatments for composting tools that experience abrasive wear throughout their use[18].

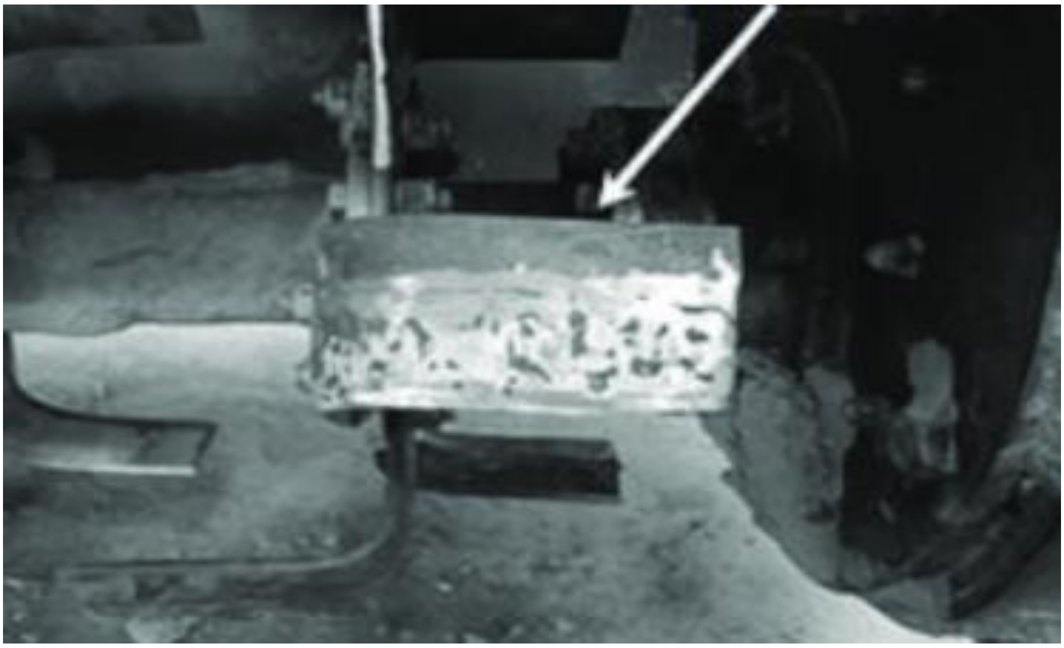

Figure 8: Worn out blade

American Society for Testing and Material (ASTM) international defines wear as damage caused by relative motion between that surface and most typically the scratches and material removal are gradual process under the motions which are mostly associated with repeated action. The surface profile, contact circumstances, and field environment determine the many kinds of related working tool wear. Four most typical kinds of we are which dominate technically are adhesive wear, abrasive wear, corrosive wear and surface fatigue, according to many researchers and investigators working on wear and surveys done by Burwell. Still, each wear process follows its own set of rules and on many times on the Mods, interacts with others. It is thus necessary to clearly determine the main source of wear and untangle a difficult problem. A study team claims that the major reason of tool damage is wear. Different abrasive wear processes resulted in material specialization to guarantee the operating resistance on wear in a certain state. Based on current state of theoretical understanding, the estimated analytic expectation of abrasive wear value in various surface contact system is not achievable because process which occur are extremely complex to distinguish[19].

IV. Material selection.

When it comes to design and product enhancement for a wide range of industrial applications, one of the most difficult challenges is choosing the right materials for any mechanism. All through the design and production process, materials serve an essential and significant purpose. Choosing the incorrect materials might result in heavy costs and, in the end, a defective product. Therefore, to get the desired result while keeping costs down and making sure it works for the intended purpose, designers need to find and use material that is appropriate for the job. Impact resistance, lightness, formability, and corrosion resistance are among the four or five attributes that designers claim is examined for every manufacturing component.

Goods design is no longer seen as a method for resolving issues. Technology and competent computing software have made it more of a decision-making process that requires accurate evaluation of design possibilities. Choosing to use resources is the essence of a choice.

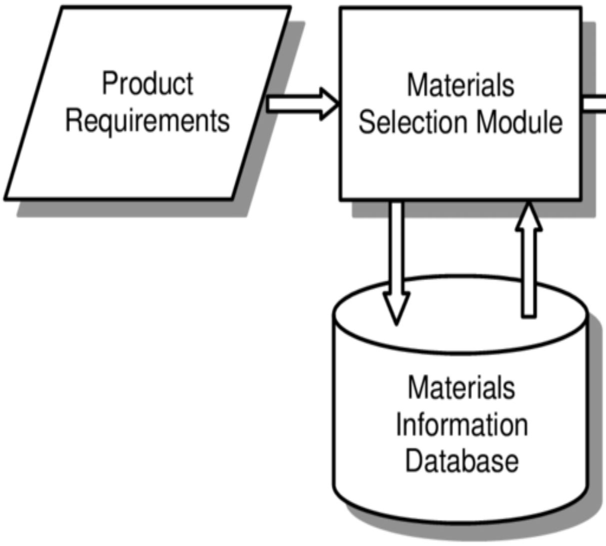

Figure 9: – The Materials Selection Processfile:///C:/Users/hp/Downloads/AnInformationProcessingApproachtoMaterialsSelection%20(1).pdf

During reaching a choice, problem solvers must create and clean up data. The decision-making group's primary challenge is the lack of available information[20]. Using the right resources and zeroing down on a specific action based on statistical and probability principles helps overcome this knowledge deficit. To help choose the best content, organize many possibilities, and rate them from best to worst, decision-making rules might be useful. This keeps the groundwork for selecting, classifying, and organizing our options while also facilitating an overall assessment of those options. A large portion of the design class time is devoted to choosing and replacing materials. It is possible to waste time and money redesigning or fabricating the intended item if the materials were not properly selected throughout the design phase. Although there is no right or wrong answer to a design problem, choosing the most important material is of the utmost importance[21].

On the other hand, expertise and knowledge are required to choose among potential substitute materials for a certain application. Because of this, a system is required to assist in the application of materials by selecting appropriate ones from a database that comprises over 100,000 items. The significant desired fabrication process and item grouping are too complex for computer assisted design approaches [22]. The knowledge-based systems (KBSs) used in AI methods (also called expert systems) are one way to choose materials. KBS is defined as an AI-powered computer approach that, with enough information on a certain subject, may mimic human problem-solving abilities. Experiment results and prior knowledge may be used to characterize materials. While numbers are used to identify data, information is used to express the relationship between data items and is often expressed in simpler terms. When assessing and choosing materials, there are simple weighing approaches [23] that may be used in conjunction with computer simulation-based resolutions. Several AI tools have been proposed at various points in time as potential solutions to the material transfer problem. There has been a lot of research on material selection difficulties for different engineering components, but additional approaches, including expert system methods, are needed to provide comparable answers. An area where expert system methods (EMSs) shine is in the selection of materials. To solve issues related to a narrow area, expert systems use computer programs that reflect knowledge about that domain. The expert system's value is twofold: first, it determines which material attributes are necessary for the product in question, and second, it searches the materials knowledge base for suitable materials that possess these properties.[24]

When it comes to designing a product, several researchers have focused on the issue of material selection. As an example, a mechanical design scientist named Ashby detailed a particular method of material selection called material choice diagrams, which showed how this perspective may be expanded to include environmental considerations. Various researchers have proposed a selection method that considers information about the environmental qualities of materials to reduce the likelihood of items meeting harmful substances [25]. Also, several academics came out with environmental materials choice diagrams to help with material choices to lessen environmental effect. Due to the unique qualities and requirements of each product, material selection is a challenging undertaking. A lot of data management across several materials is required for the material selection process. It is impossible for a production engineer to know everything about any material. To further educate the production engineer on all the unique materials, it may be necessary to assemble a team of specialists. But it's challenging and expensive to have that kind of staff. Practical and economic considerations may lead to the employment of an expert system based on information extracted from experts rather than an expert team.

V. Effective Factors in Materials Selection in Engineering Design

Choosing the right material for a job is an involved, time-consuming, and often costly procedure. In most cases, more than one material may be used for a given task; ultimately, choosing one involves weighing the pros and cons of each option. When choosing materials, there are several considerations to keep in mind. Naturally, there are cases when specific material requirements are established right from the start of the design process. Although the necessary requirements do predominate in such cases, considerations usually narrow the field down to a single material from among many options[26].

Even though most of these sources describe design as an interactive process including both technical and non-technical aspects, the engineering-based sources influence heavily towards the technical side. According to Patton [27], there are three primary considerations for a designer when choosing a material: (1) service, (2) fabrication, and (3) economics. The service criteria, in his view, are paramount. Dimensional stability, resistance to corrosion, sufficient strength, hardness, toughness, and heat resistance are typical service needs that the material must meet. The material also must be malleable and easy to combine with others. Under the umbrella term "fabrication requirements," Patton classifies several material characteristics. ***Lastly, he says that a designer's job is to make the product and its production as cheap as possible. If the savings in machining cost are large enough, it may be worthwhile to use a more costly free-machining metal instead of a cheaper standard metal.***

▪ Used Technologies and Manufacturing Methods

Following techniques and methods (cold forging) were used in the design of hatchet blade.

Figure 10: Long bar of steel S235. (our own pic)

a) Cutting: Thin long bars (fig.10) of steel (S235) are cut in the desired shape and size using shear machine making it appropriate for the hatchet blade. The machine (Fig. 11) maintains the precision in every cut, allows the steel to be in a shape which is needed for the hatchet blade. The process is efficient because of the high pressure of the machine, provides fair and smooth cuts by minimizing any waste and reduce further process like shaping and finishing.

This method gives the liberty to the steel to be in its own structural integrity without any changes, which is required for the durability and sharpness of hatchet blade.[28]

Figure 11: Cutting in required pieces. (own pic)

b) Drilling: Laser drilling (Fig12) offers several advantages for creating holes in a hatchet blade when clearance is limited or not given. Because of the different process of material removal, laser drilling generates superior quality with shorter pulse width and greater peak intensity. Because the thermal diffusion depth of ultrashort pulse laser is either equal to or less than optical penetration depth, the thermal damage to material is minimal.

Figure 12 Leser cutting or drilling.
https://www.accteklaser.com/laser-drilling

Figure 13: Drilled Hole (own pic)

Experimental and theoretical data show that the main drilling process for this application is not one of surface absorption and conduction inward but rather one in which laser energy is absorbed across the body of the material. Accurate creation and measurement of the depth and form of holes drilled in S235 have been accomplished (Fig.13).

More effectively and cleaner method of drilling and creating holes at deeper depths is proven to be laser drilling. Laser drilling offers one of the benefits in terms of possible reduction of drilling time. By not touching the item, lasers save drilling time and thereby save the need to stop and replace a mechanical bit.[29]

c) Bending: To make the blade in an appropriate form and achieve the required shape, press machine was used. The press bends the steel S235 in a very controlled manner by applying the required amount of pressure and making sure that the curvature matches design specifications. The benefit of this process is that it provides precise and in line shaping of the blade while maintaining its structural reliability. This process ensures uniform bending, trying to avoid the any possibilities of cracking or weakening the steel. Finally, the blade takes on the desired form and now it is ready for other mechanical processes like finishing and sharpening without the change of its natural strength[30].

Figure 14;Press or Shaping Machine (our own pic.)

Figure 15: Blade After shaping (own pic.)

To create designed shaped and achieve the specific bending requirements, we have developed a special die (Fig. 13) which is attached to the press machine. This custom-made die was designed to create the specific shape, match the curvature and bend it into the required form (Fig. 14). It allows efficient shaping while making sure that it is fulfilling the blade’s required dimensions and making the blade appropriate to its performances.

▪ Another Method (hot forging) to Shape the Hatchet Blade,

a) Forging: Forging is a process which provides strength and toughness to the S235(low carbon structural steel).

It is done by heating the steel up to 1000 degree Celsius (from 900 to1200°C). After heating we apply the force like hammering and pressing to make the required shape.

Figure 16: Heated piece of the blade

The metal's grain structure is straightened during this process, enhancing the material's durability

Figure 17: Shaping in a press.

which is essential for a KSN rotary blade that must endure significantmechanical s tress in the operations. Upon forging, heat treatment becomes a vital function.

The principal thermal treatments are:

I. *Normalizing:* The blade is heated to around 900°C and then air cooled to enhance the grain structure.
This enhances toughness and ductility, hence decreasing the likelihood of brittl e fractures.

II. *Quenching and Tempering:* this process requires cooling of the product in certain kind of liquid (either oil or water) according to the requirement. This process is required for making the surface hard. This increases brittleness, which can be reduced by tempering — a technique that involves heating the blade to a lower temperature, about 200–600°C, to achieve a balance between stiffness and pliability.
The thermal stresses during cooling may generate intricate interior microstructures, such as martensite or pearlite, contingent upon the cooling rate of the blade.
These stages provide differing levels of hardness and toughness.[31]

NOTE,

- Forging provides higher strength, durability and toughness due to the refinement of grain of the work piece which makes it appropriate for high stress applications. It is high-cost process with lower precision and further finishing is required.
- On the other hand, pressing (especially cold pressing) provides efficiency, precision and mass production in low-cost by compromising in toughness and grain refinement. *We had chosen this method to manufacture the cheap and the best form of the blade to fulfil the customer requirements.*

b) Surface Coating and Their Types.

Surface coatings are essential for improving wear resistance, giving the protection against corrosion, and adding the good looks. The technologies that are used to protect the KSN hatchet blades are…

I. *Painting:* This serves as the essential protective layer applied to S235 steel. Applying paint helps keep moisture away from the blade's surface, which ultimately minimizes corrosion. Nonetheless, the drawback in it that it may diminish rapidly in turning the waste where the blade frequently meets hard composting materials.

Figure 18: Painted Hatchet blade.

II. *Black Oxide Coating:* This involves a chemical process conducted at almost 150°C, resulting in a thin oxide layer forming on the surface. This increases the resistance to mild corrosion and provides the blade with a smooth, black matte finish (does not reflect light or appear shiny). This method provides the resistance against wear, also it helps in minimizing the friction while turning the compost.

Figure 19: Black Oxide Coated Hatchet Blade.

III. *Nitriding:* Nitriding is a sophisticated method for enhancing surface hardness. Nitriding is the diffusion of nitrogen atoms into the surface of steel at high temperatures, leading to the development of a hard nitride layer. Nitriding distinguishes itself from conventional quenching and tempering by providing a very hard surface (900-1100 HV) without the need of quick cooling. This procedure significantly improves wear resistance and extends the blade's longevity. This is ideal for use in demanding environments such as composting or tillage, where the blade experiences intense friction and wear.

Figure 20: Intruded Hatchet Blade.

Advances in Material Science Relevant to Rotary Hatchet Blade Manufacturing:

Modern manufacturing processes have made it feasible to create turning hatchet blades that are superior in design and performance, particularly for the use of turning organic waste into semi compost. This modification's primary objective is to improve the blade's durability, cutting performance, and resistance to wear. The important advancement is the use of micro alloyed steels. Small amounts of alloying elements such as vanadium, niobium, or titanium are introduced into the steel to refine its grain structure. This enhances the blade's toughness and wear resistance, which are important for the tough conditions faced during turning operations. Micro alloyed steels also help to improve fatigue resistance, which helps the blades last longer even under continuous use in harsh environments[32].

Also, the advancements in surface engineering technologies have been equally exciting. Modern nanocoating's and advanced nitriding methods can achieve higher levels of hardness and resistance to wear, corrosion, and friction beyond what traditional coatings (like the DLC) ever could. An ultra-thin layer of a ceramic based coating, such as titanium nitride (TiN) can be added to increase hardness and therefore blade life without affecting sharpness. They reduce blade and soil friction improving efficiency by reducing drag[33].

Hybrid manufacturing technology combines those materials with traditional forging and even newer methods like 3D printing, otherwise called additive manufacturing. This allows for a wide range of blade geometries and the material distribution has been optimized. This ability to tailor the mechanical properties of specific areas of a component so they can be optimised (e.g. stronger at the edge of the shears for cutting and more flexible at the action points, again taking impacts well) is another important thing[34].

Combined, these material innovations result in stronger, more efficient and longer-life rotary hatchet blades that can better live through the aggressive environments when deploying composts or performing tillage. These developments do not only make the machines work better but they also save energy by reducing the power the machine uses to operate.

▪ Designing Method of Hatchet blade:

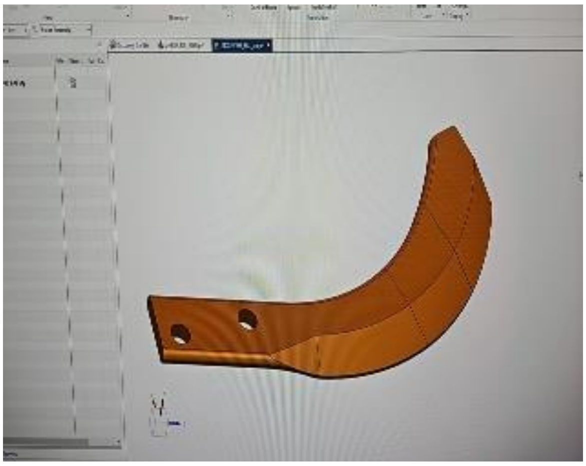

Figure 21: Blade model (without bending)

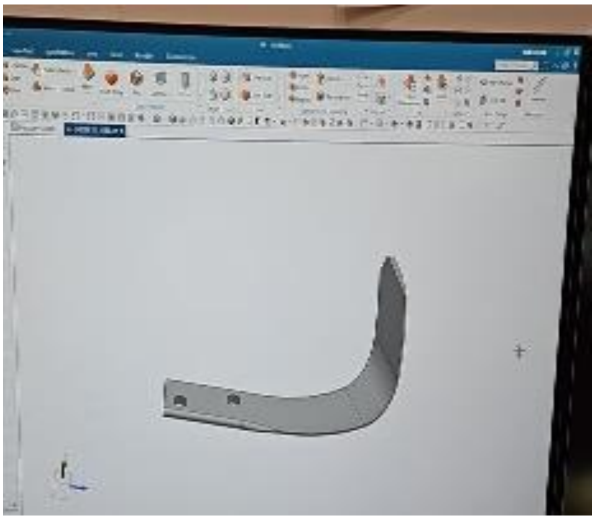

Figure 22:Bent model of Hatchet blade.

The process of designing anything is not an easy task. Throughout the course of history, the design of a wide range of objects has been constructed using paper and other drawing instruments. CAD (Computer Aided Design) tools, on the other hand, are responsible for the significant bulk of the designing work that is carried out in the modern day. Numerous software programs, including Auto CAD, CREO, ANSYS, Solid Works, and a great deal of others, are among the many that are now accessible on the market. Each of these software applications has its own one-of-a-kind set of skills, and they are used by certain industries specifically for the purpose of accomplishing specific goals. Certain computer-aided design (CAD) software allows for the creation of drawings and three-dimensional models of the product (Fig. 21), in addition to allowing for the simulation and structural analysis of the model under consideration. The production of drawings is not the only activity that is carried out together with these activities. *CREO supplies all the components that are required to create and evaluate the blade, even before the actual manufacture of the physical model. This process begins even before the actual manufacturing of the physical model. This is done before the actual development of the physical model (Fig.22).*

Design engineers may get significant benefits from computer-aided design (CAD) technology because it provides a wide range, which makes the design process more straightforward. To facilitate the development of the model in the future, the capabilities of computer-aided design (CAD) software make it possible to modify the work that was supposed to be done later[35].

In today's industry, the finite element method and three-dimensional (3D) modelling are gaining popularity and are becoming more popular. There is a wide variety of engineering specializations that may give several examples of uses of finite element modelling and three-dimensional modelling, hatchet blade is one of them. Enhancing the performance of the hatchet blade in the field may be accomplished by reducing both its weight and its cost as much as possible. The use of computer-aided design analysis, which is the use of finite element methods and three-dimensional solid modelling, is becoming more common in the industry.

Figure 23: Rare view of the model.

Today's highly competitive environment brings the manufacturers to construct their products in the most effective manner possible and hatchet blade has also followed the same pattern[36]. The CREO 3D parametric design tool was used in this study to create a model of a rotating hatchet blade, which was afterwards built.

▪ Economic Considerations in Material Selection:

The competitive market, driven by enhanced product consumption, forces product designers to prioritize materials more than before. Materials have been thoroughly examined in the fields of science and engineering for many years. Current materials selection resources may provide valuable information on the technical (physical, quantitative) properties of materials. Designers use intangible elements to convey their objectives, attribute meanings to their creations via judicious material selection. Nevertheless, the competitive market resulting from the enhanced consumption of products and materials has forced product designers to consider some intangible factors in addition to the technical and sensory elements. Designers have begun using materials to provide significance to their goods.[37]

One may find several instances that support this claim. For example, metal looks robust and strong and imply accuracy; so, designers may highlight the technical excellence and high-level engineering of a product by using metal. In science and engineering, materials have been well investigated for years. Current knowledge on the technical (physical, measurable) features of materials may be obtained from existing materials selection sources, therefore enabling their intended expression.

Choosing a material for a certain use is a careful, time-consuming, costly procedure. Almost typically more than one material is appropriate for an application; the choice is a compromise that delivers certain benefits as well as drawbacks. Choosing materials calls for careful consideration of numerous elements or restrictions. Of course, there are rare cases where the definition of a material's criteria starts the design process. While in such circumstances the necessary criteria control the choice process, most of the time one material within a range of materials is chosen relying on certain criteria.
A designer choosing a material must consider three main criteria: service needs, manufacturing requirements, and financial constraints. Needs for services are top priority. Commonly including dimensional stability, corrosion resistance, sufficient strength, hardness, toughness and heat resistance, the material must stand up to service requirements.
The material must also be fit for shaping and combining with other materials. Designer's goal is to lower production and general cost of the product. For instance, a more costly free-machining metal might be used in place of a standard metal as the machining savings would exceed the higher cost of the more expensive metal.
Another source identifies the two fundamental criteria in materials selection as the "mechanical properties of materials" and the "cost".
Mechanical characteristics of materials govern its use and surroundings, the appreciation on the fundamentals of the mechanical properties of materials promotes designers to investigate new application areas for new materials and helps material science to advance. Among the most crucial mechanical characteristics are noted strength and stiffness, quality and durability of the surface[38].

Considering all above, we have selected S235 for hatchet blade. There are several economic advantages of choosing S235.
S235 is an affordable material compared to more specialized steels, making it attractive if you're looking to keep costs down. It can be easily worked and shaped, without the need of any special tools i.e. easily machinable making it suitable for low-cost manufacturing. On the other hand, if it is required to use it for harder tasks or specialized work, we can consider having it heat treated to increase its wear resistance which may increase the cost.

S235 is available in the market in excess so there is no supply chain problems or delays, ensuring everything is quick and cost effective. It is also lightweight, which results in lower transportation costs. S235 is also environmentally friendly, it’s recyclable, which is another advantage, because sustainability is important in the project. In the end, S235 strikes a good balance between affordability and ease of manufacturing.

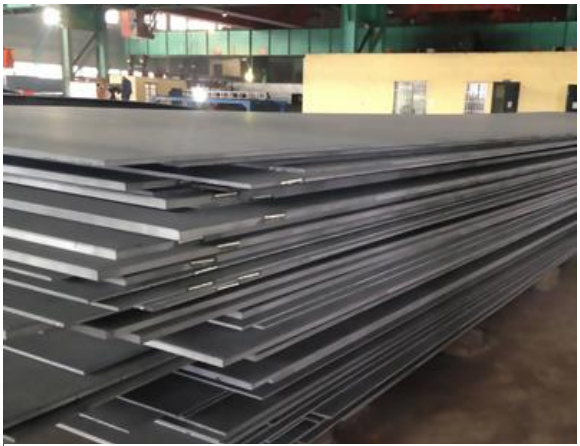

Figure 24: S235 steel.

https://www.steelsino.com/s--s--s-steel-352.html

▪ Economical Differences Between Original Blade and Manufactured Blade:

We have manufactured a hatchet blade for composting machine which has several economic advantages comparing to the sample (original) blade without compromising Its functionality, describing below.

Parameter	Details
Description of Product	Design and manufacturing of a hatchet blade for composting machine.
Used Material	S235 steel.
Economic Benefits	Reducing the cost of the product without compromising the functionality of the blade.
Material of The Original blade	High-carbon steel or boron steel.
Cost Comparison	Cost of Original blade: 10 USD per blade almost. Cost of new blade: 6 USD approximately.
Reason for Cost Reduction	Selected S235 steel which is more affordable and has cheaper manufacturing processes.
Properties of Selected Material	-It has sufficient hardness for the required application -It is having sufficient wear resistance for composting necessities. -Its durability is also good for necessary strength
Balance of The Performance	It provides required strength and efficiency for composting machine.
Limitations	S235 material is less hard and not exact wear resistant as boron or high-carbon steel, but it is sufficiently robust for composting application.
Other Benefits	Reduced Material cost, Efficient manufacturing processes, reduced material cost, more affordable for cost sensitive customers.

Manufacturing Strategy	We have focused on cost effectiveness while meeting the customer needs for affordability and performance.

Conclusion

In conclusion, this study clearly shows that it is feasible to design and manufacture an economical blade for composting machine without even compromising its functionality. By careful selection of material, adopting appropriate manufacturing method, improved blade geometry, the redesigned blade can achieve the purpose of manufacturing with reduced cots compared to the original blade. Designing of new blade can reduced the challenge of high-cost component of composting machine and make it easily accessible in the market, especially for the budget conscious market. The purpose of this study is the evaluation of materials and manufacturing methods to make balance between cost and effectiveness of the blade. By a comparative analysis of the material properties, cheaper or economical material has selected, which has required hardness, resistance and durability required for composting. The results of this study have major impact on composting fields and serving cheaper, efficient and economical solutions for the manufacturing of the blade. By minimizing production cost manufacturer can make more economical composting machine, motivating sustainable waste management by making it easily accessible in the market.

▪ DECLARATION

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Year of publication: 2024

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