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Toward SLM Cost model estimation: stainless steel case study

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ABSTRACT

Additive manufacturing is a capable process to produce three dimensional components from raw material and 3D design data. This layer-by-layer operating process has many advantages including high geometrical freedom to produce complex parts with reduced cost and applied especially in the aerospace, medical and automotive industry.

One of the metal AM processes is Selective Laser Melting this technology is an effective manufacturing technique to build metallic and functional parts.

The aim of this study is to perform an economic assessment of Selective Laser Melting by developing a cost estimation model to estimate the process cost along the process life cycle cost. The cost of manufacturing is the key point for decision making to compare the Selective Laser Melting technology with different manufacturing technologies. The cost estimation is profitable also for engineers at the preliminary design. Production costs are studied to find out parameters influencing the Selective Laser Melting process such as machine cost, material, and post processing and how is the process cost could be optimized. A case study on Selective Laser Melting of stainless steels is presented to illustrate the cost model. This work presents a more realistic cost model of Selective Laser Melting based on the activity approach and including all steps of manufacturing with SLM such as part design and post processing such as heat treatment. This research enables us to understand the entire value network of Selective Laser Melting. It has been found that, the machine cost was by far the largest factor in Selective Laser Melting, followed by the post processing cost.

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1. INTRODUCTION

Additive manufacturing (AM) is a layer-by-layer production process that enables the formation of solid things through the use of a laser or an electron beam. This fabrication technique usually used for rapid prototyping, a process of developing prototypes as fast as possible to acquire a final product design [1]. It is a series of techniques used to model a scale prototype of a physical component or an assembly using computer aided design data [6]. The American Society for Testing and Materials, (ASTM) defines the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining [2].

Hopkinson and Dickens, 2003 examined the economics of rapid tooling and rapid manufacturing [8]. The authors created a technology that enables the production of finished goods on a big scale. Hopkinson and Dickens published a cost analysis that compares injection molding to layer manufacturing technologies (fused deposition modeling, and laser sintering, stereolithography) in terms of unit cost for components created in varying quantities. The results showed that layer manufacturing methods are more advantageous for specific geometries, up to reasonably high production volumes (of the order of a thousand pieces). The expenses of the parts were divided into three categories: machine costs, labor costs, and material costs. Because of its modest cost impact, energy was overlooked.

Ruffo et al. Investigated the manufacturing costs of the same part obtained by Hopkinson and Dickens and obtained using laser sintering [14]. Their cost model breaks down the cost structure into several activities, activity-based costing. This method entails defining the actions involved, calculating the expenses of each activity, and totaling the costs. The expenses of activities are then divided into direct and indirect costs. The cost of material is classified as a direct cost. Labor, machine, production overhead, and administrative overhead are all distributed indirectly. The overall cost of a single construction project is the sum of direct and indirect expenditures. The direct costs are determined by the amount of material consumed, whereas the indirect costs are determined by the length of the process. An empirical method is used to estimate build time. Ruffo et al. developed an estimating technique for the Selective Laser Sintering procedure. This method is valid only when producing many copies of the same geometry.

Baumers et al. [4] were the first to investigate the economic and energetic aspects, as well as the time required to achieve the AM building part. Ruffo et al. developed an activity-based cost estimator; energy expenses were classified as direct, total build time was estimated, and energy consumption was accurately analyzed. According to Baumers, the examination of the build's unused capacity problem is critical due to the indirect costs of AM and the presence of a fixed element of time consumption (for each layer and for each build). Hopkinson and Dickens assume that there is no surplus capacity because the machine's chamber is always filled of parts. Ruffo et al, model’s is also predicated on the assumption that any surplus capacity is left unused. Another noteworthy finding made by Baumers et al. is that break-even cost models may be unable to convey the possibilities of geometrically less restricted manufacturing techniques when producing a complex product. Furthermore, AM suffers from the drawback of not being able to provide the scale economies that conventional manufacturing techniques do. Baumers et al. used an activity-based cost estimator similar to the one developed by Ruffo et al. The cost estimate for the construction is created by combining data on all indirect and direct expenditures spent. Unlike Ruffo et al., energy costs are classified as direct costs.

The calculation of product costs is crucial in the evaluation of additive manufacturing [12]. It serves as the foundation for determining the most important decision variable in AM, which is the product cost. Cost estimation is inextricably tied to business success [9]. Overpricing can result in a sale being lost, whilst underpricing might result in a financial loss [7]. The figure is frequently used to show how, in traditional production, costs decline as quantities rise, whereas in additive manufacturing, costs remain essentially constant [5].

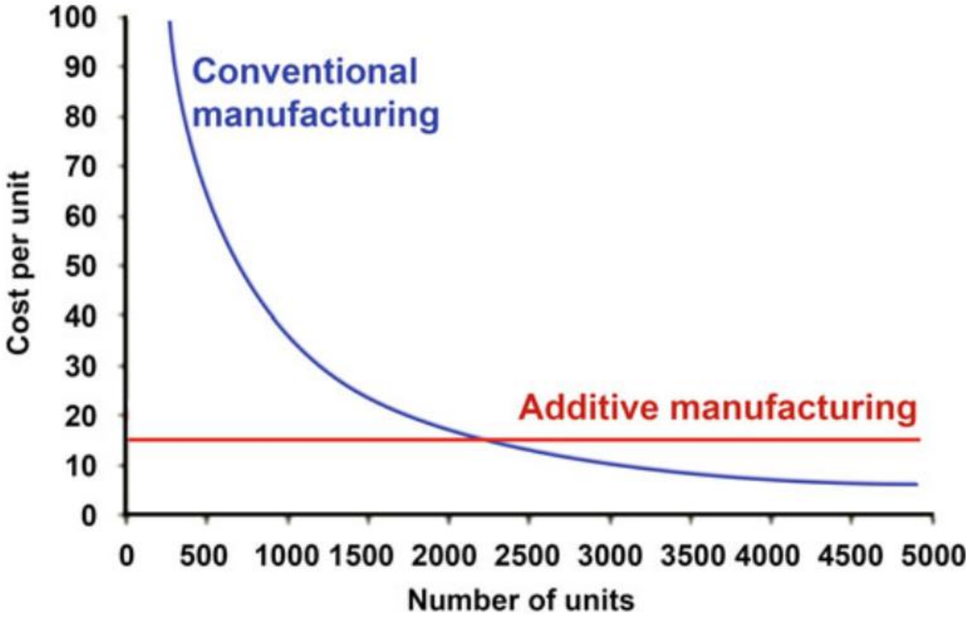

Figure.1 comparison between cost with conventional manufacturing and AM [19]

Researchers developed many cost models for additive manufacturing to estimate total cost of additive manufacturing technics, we can divide these models to three main approaches parametric approach, break down approach and activity-based approach.

1.1. Parametric approach cost model

Ruffo et al. developed cost estimating relationships for SLS using a parametric and engineering approach. The total cost was determined by multiplying the direct and indirect costs (material consumed) together (time to build the part).[14] The model was developed by expanding on a preceding model by Hopkinson and Dickens by assuming a more realistic 57 percent machine utilization rate. Additionally, they considered factors such as the labor cost of the product and the material recycling restrictions (thermal treatment of powder). The break-even point was increased to 15,500 pieces from 14,000 pieces (as computed by Hopkinson and Dickens).[8] When compared to the previous model, the SLS's material cost relevance dropped to 33% from 78%. Additionally, this model determined that machine investment and maintenance expenses contributed 38%, rather than the previously assumed 24%. Ruffo et al. developed a model that took into account the potential of machine failure, as well as post-processing and lead-time costs [13].

1.2. Break down approach cost model

Atzeni and Salmi developed cost models for additive manufacturing (AM) processes such as selective laser sintering (SLS) and high-pressure die casting in order to predict the cost of an aeronautical component.[3] The cost of SLS was broken down into four categories: material, pretreatment, processing, and posttreatment. The material cost was determined by multiplying the material's mass by its unit cost per kilogram. Pre-processing expenses were calculated using product setup time and operator rate. The processing cost was determined by multiplying the machine's cost by the number of pieces used in each build. The cost of post-processing was approximated using the time required for post-processing, the operator rate, and the cost of heat treatment. Even when metal pieces are involved, the cost comparison demonstrates that SLS is the most cost-effective method for small to medium batch production [11]. The cost analysis determined that the most important component is the machine's cost, followed by the cost of the materials. Yim and Rosen developed a cost estimation equation based on a break-down technique and proposed an equation that included four costs: machine purchase, machine operation, material cost, and operation cost.[18] The build time was factored into the labor cost when calculating the purchase price. The operational cost was determined by multiplying the operating rate by the construction time. The construction time was calculated by factoring in recoating time, material processing time, and delay time. The material cost was determined by multiplying the volume of the product by the material rate. The labor cost was calculated by factoring in the labor rate and the time required to finish the work. Cost estimation was performed using specific models for SLA, FDM, and Polyjet, and the results were compared to quoted pricing. The data indicated that the estimates made by the models were reasonably accurate and may be used to select an AM technology [16-17].

1.3. Activity approach cost model

In this approach with regard to labor costs the build time was included while calculating the purchase price. The operational cost was computed by multiplying the operating rate by the construction time[10]. The construction time was calculated by incorporating recoating time, material processing time, and delay time. The material cost was estimated by taking the product's volume, including the support structure, and multiplying it by the material rate. The labor cost was calculated by combining the labor rate and the time it took to accomplish the task. Specialized models for SLA, FDM, and Polyjet were built for cost assessment, and the results were compared to quoted pricing. The data demonstrated that the forecasts of the models were pretty accurate and may be used to select an AM technology. According to the data, machine costs were the most major cost factor, followed by material costs. They also discovered that the expenses of data preparation for pre- and post-processing jobs might be cut even more. It should be noted that the build rate, usage rate, and machine investment assumptions can all be changed to produce a more realistic estimate. Schröder and colleagues created a software solution based on a time-driven-activity-based costing paradigm.[15] They investigated the costs of additive manufacturing methods and conducted sensitivity analysis to determine the cost drivers for sample items. The model was developed by taking waste material recycling, the support structure, manufacturing time calculations, the maximum number of products that can be manufactured concurrently, the complexity of product design, post-processing time, and the integration of quality management methods into account. The following seven key processes were identified using the activity-based costing technique: (1) planning and design; (2) material processing; (3) machine preparation; (4) manufacture; (5) post-processing; (6) administration; and (7) sales and quality. The model was developed to estimate expenses based on 77 different inputs. These inputs were further subdivided into process-specific data. The outcome of the sensitivity research revealed three significant findings: (1) Machine investment was critical; (2) post-processing activities for tiny bodies and massive numbers have a lot of opportunity for improvement; and (3) economies of scale can be addressed in smaller items, while larger products can be independent of the requested amount. According to Costabile et al., the cost model of Schröder et al. covers the cost of sales administration, but the activities involved in sales and administration were not detailed. An AM cost model should include manufacturing costs for cost accounting.

Cost models are used to forecast the cost of a product based on different manufacturing techniques. Understanding the primary cost drivers is the foundation for creating a cost model that will allow you to optimize cost-cutting approaches. Many studies have been conducted to breakdown the cost drivers for Selective Laser Melting, as shown in the table below, and it reveals that raw material cost, machine cost, and labor cost are the primary characteristics to consider during a cost model estimation.

Table 1. cost drivers for different models

Variable	**Additive manufacturing**	**Traditional manufacturing**
Flexibility in the manufacturing process	YES	NO
Making several pieces simultaneously	YES	NO
Making several designations in a same batch	YES	NO
Manufacture of complex shapes	YES	NO
Diversity of materials	YES	NO
High resolution parts	YES	NO
Elimination of several intermediate steps	YES	NO
Increase in the gain	YES	NO
Diminution of manufacturing time	YES	NO
Possibility to create monobloc parts	YES	NO
Large series manufacture	NO	YES
Small and large series production	YES	NO
Amount of work	NO	YES
Economic	YES	NO
Continuous sequence of production series	NO	YES
use of several processes to produce a single piece	NO	YES
The time of manufacture depends on the size of the piece	YES	NO
Ecological	YES	NO
Less cost of logistics	YES	NO
Elimination of production tools	YES	NO

We identify eight process phases for a generic AM process:

CAD design
Plan the build
Machine preparation
Powder preparation
Gaz preparation
Building
Part removing
Post processing and heat treatment

Following that, we will examine each step and determine their unit cost per part then calculate the total cost.

This paper proposes a more accurate cost model of Selective Laser Melting based on the activity method, which includes all processes of SLM manufacturing such as part design and post processing such as heat treatment. This study allows us to comprehend the complete value network of Selective Laser Melting.

2. Cost model development

In this study to understand the cost drivers the additive manufacturing cost analyzed by dividing every step of the fabrication workflow. For every SLM process there are four main tasks to be achieved build preparation, building process, finishing and part control every task include many drivers as shown in the figure below.

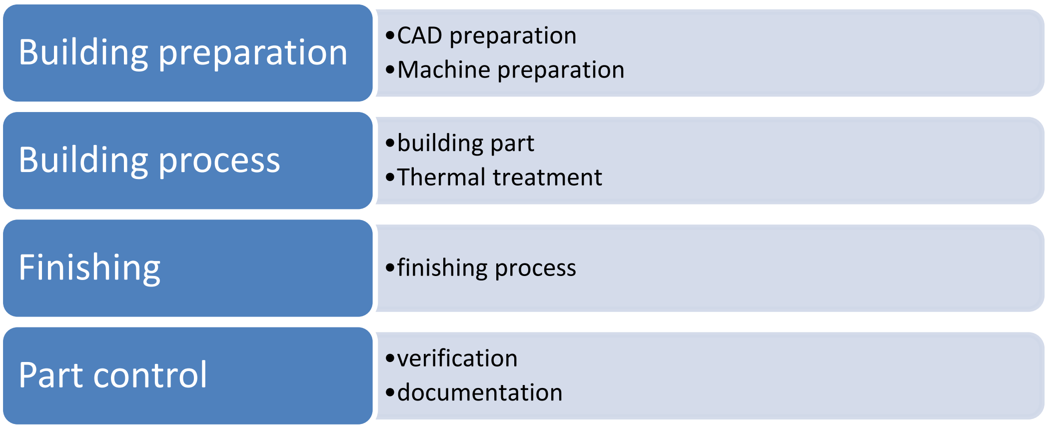

Figure.2 Cost drivers for Selective Laser Melting

2.1. Cost model assumptions

To develop a straightforward cost model some assumptions have been established to provide a reliable approach related to SLM cost as given bellow.

- The machine is operational 90% of the time.
- Only 50% of the material is recycled in order to maintain the product's quality.
- Under the assumption that one operator is continuously handling one machine, the hourly rate cost per operator is 40MAD/hr.
- Overhead, electricity usage, and space renting are not factored into any calculations; earlier research has shown that these variables can increase total costs by between 1 to 10%.
- For one year, the system creates only one sort of part.

2.2. cost model equation

For our study, the equation bellow shows the cost model calculated to fabricate one part we used an activity approach of the different steps necessary for the production of parts by the 3D printing process, including the intervention of the labor. This allows having an idea of all the steps to be performed in chronological order, in order to calculate their costs independently. As activities, we have the logistics, the raw material, the choice of design, the machine, the post-processing.

$$C_{tpart} = C_{mt} + C_{mc} + C_{pp} + C_l$$

$$C_{tpart} = C_{mt} + C_d + C_{mc} + C_{pp} + C_l$$

- Where C_{tpart} is the total cost of part and the other costs are as follow:
  - C_{mt}: material cost is equal $\frac{Mat\ Price}{N}$
  - C_d: design cost is equal to $C_d = t_d \times (C_l + C_o)$
  - C_{mc}: machine cost is equal to $\frac{C_{purchase} \times T_{build}}{N \times 0.9 Y_{life}}$
  - C_{pp}: post-processing cost is equal to $(labor\ rate + Machne\ rate\ ) \times \frac{T_{pp}}{N}$
  - C_l : labor cost is equal to $labor\ rate \times \frac{T_{build}}{N}$

Table.2 costs description

Cost	Description	Unit
C_{tpart}	Cost fabrication of one part	MAD/part
$Mat\ Price$	Material price	MAD/Kg
N	Number of parts per platform	Parts/platform
$C_{purchase}$	The purchase cost of a machine	MAD
T_{build}	Time to build one platform	Hours/platform
Y_{life}	machine useful life	Hours
T_{pp}	Time of post processing of part per platform	Hours/platform
$labor\ rate$	Cost of labor per hour	MAD/hour
$Machne\ rate$	Cost of utilizing the machine per hour	MAD/hour

3. SLM cost Breakdown

3.1. CAD design

Designing for 3D printing means changing an existing design or beginning from scratch with a real design for additive manufacturing (DFAM) approach. To improve the function of the part, computer simulation, generative design, and topology optimization can all be used. The printing process and material selection are usually done during the design phase. The additive manufacturing of parts first requires a design using either a software or a scanner. The use of software is the most common in the industry, whose design is done by designers or technicians, its cost depends on the type and the update of the software used, as well as the cost of the designer depends on the complexity of the part. On the other hand, the use of a scanner requires a point cloud processing of the scanned part performed by a specialized technician.

For the choice of concept by design its cost takes into account the time of design (t_d) the cost of labor (C_l) without forgetting the overheads cost (C_o) such as the cost of the software and the costs of update calculated by the following relation:

$$C_d = t_d \times (C_l + C_o)$$

3.2. Plan the build for additive manufacturing

Make a plan for the construction. This stage may include selecting component orientation, adding support structures, packing or nesting several pieces together, and configuring printer parameters such as layer height, laser spot size, feed rate, and so on, depending on the SLM machine used. Its cost takes into account the time of part preparation $(t_{part\ pre})$ the cost of labor (C_p) without forgetting the overheads cost (C_o) such as the cost of the software and the costs of update calculated by the following relation:

$$C_p = t_{part\ pre} \times (C_l + C_o)$$

3.3. Machine preparation

The step of machine preparation is included in the stage of building preparation. This pre-processing step entails a few critical procedures that must be followed in order for the building process to run smoothly. To begin, the procedure of leveling substrate in the SLM machine and locking the build platform is required. The cost associated with this operation (C_leveling) consists mostly of the time required to complete the operation (t_leveling), the labor cost (Clabor), and the machine cost (Cmach), which corresponds to the total machine hourly rate, as indicated in section 3.3.3.2. The following calculation calculates this cost:

$$C_{leveling} = t_{leveling} \times ((C_{machine}) + C_l)$$

3.4. Powder drying

The production of high-quality additives necessitates the use of high-quality raw materials. Powder materials utilized in the selective laser melting (SLM) process, such as stainless steel 316L, is sensitive to humidity. The chemical features of the powder can alter substantially if it absorbs too much water from the surrounding air, resulting in a decrease of print quality. To guarantee that the raw material fits the manufacturer's specifications, all storage conditions should be carefully monitored, whether inside or outside the printer and the powder must be heated up with an oven at 80°C to eliminate moisture from the powder and ensure that it’s dry from water particle.

3.4. Powder sieving

The next step is powder preparation, which usually entails sieving the metal powder and loading it into the powder feeder. the metal powder that is used in the additive manufacturing process must be sized to a very tight distribution for Selective Laser Melting the range is from 44 microns to 15 microns, as shown in figure 3.

Figure 3. powder sieving

3.5. Inert gas preparation

Then, as indicated in the following equation, inert gas preparation, which essentially consists of supplying the gas in the chamber, The necessity to produce components in a controlled environment and avoid the introduction of any possible contaminants into the materials is one of the primary issues in metal additive manufacturing (AM). Inert gases like argon and nitrogen produce an inert, or chemically inactive, atmosphere, allowing parts to be fabricated to the rigorous standards necessary for metal parts in the aerospace and automotive industries.

AM procedures like directed energy deposition, electron beam melting, selective laser sintering, binder jetting, and powder bed fusion may all be done in an inert atmosphere without the risk of contamination from reactive gases like oxygen and carbon dioxide. is dependent on time og gaz prepareation and supply $(t_{gaz\ pre})$, labor cost (C_l),, and inert gaz generator machine cost $(C_{inert\ gaz\ generator})$.

$$C_{gaz} = t_{gaz\ pre} \times (C_l + C_{inert\ gaz\ generator})$$

3.6. Part removing from machine

After the printing finished, the operator must handle the powder that was not used by machine and remove all powder traces from part and substrate, this powder is collected to be recycled this depowering operation is essential, the recycling procedure start by sieving the collected powder and heating it up in an oven to remove water particles, from other hand the difficult to handle areas where powder still remain in the machine are cleaned by aspire however the aspired powder could not be recycled remain unused inside the aspirator.

its cost takes into account the time of removing part and cleaning machine including the powder recycling process $(t_{removal})$ the cost of labor (C_l) without forgetting the the cost of using aspirator (C_{asp}) calculated by the following relation:

$$C_{part\ removal\ from\ machine} = t_{removal} \times (C_l + C_{asp})$$

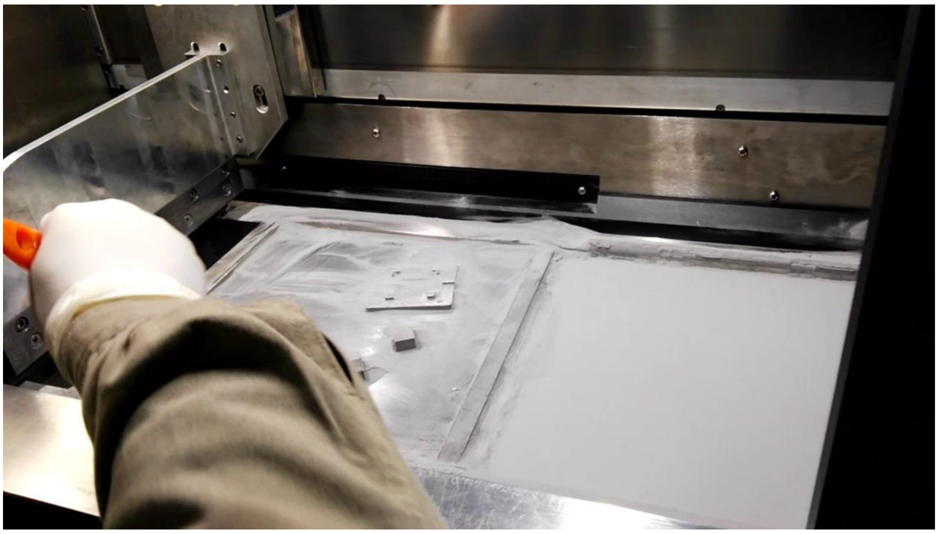

Figure 4. Machine de-powdering

3.7. Part removal from substrate

Metal additive manufacturing (AM) users have two main options when it comes to removing their parts from the build plates onto which the parts were printed: sawing using a band saw and electrical discharge machining (EDM). For our case we use band sawing its cost takes into account the time of removing part and cleaning machine including the powder recycling process (t_{sawing}) the cost of labor (C_l) without forgetting the the cost of using aspirator $C_{bandsaw\ machine}$ calculated by the following relation:

$$C_{part\ removal\ from\ substrate} = t_{sawing} \times (C_l + C_{bandsaw\ machine}\ )$$

3.8. Surface and finish substrate

It is frequently necessary to post-process and finish components manufactured using Additive Manufacturing processes in order to meet the required specifications or improve attributes such as surface quality, geometrical accuracy, and mechanical properties. Surface roughness ratings for selectively laser burned metal objects typically range from 15 to 40 micrometers. By integrating well-established fabrication methods at the end of the AM process chain, most physical attributes can be improved.

Because of the exceptional quality of metal products created utilizing AM methods, a wide range of metal-machining finishes may be used to meet surface quality and geometry requirements. its cost takes into account the time of removing part and cleaning machine including the powder recycling process $(t_{finishibg})$ the cost of labor (C_l) without forgetting the the cost of using aspirator $C_{finishig\ machine})$ calculated by the following relation:

$$C_{part\ finishing} = t_{finishibg} \times (C_l + C_{finishig\ machine})$$

3.9. Heat treatment

When an item has been 3D printed via SLM-style processes, it is almost always advisable to apply a heat treatment to conclude the operation. There are a couple of good reasons for doing so.

- First, heat treatment can have de-tensioning effects. During the printing phase, materials can accumulate internal stresses and tensions, which compromise mechanical properties – weaknesses that heat treatment can reverse.
- Second, heat treatment can be used to optimize the properties of printed products, adding extra features such as heat resistance or tensile strength.

its cost takes into account the time of removing part and cleaning machine including the powder recycling process (t_heat treatment) the cost of labor (C_l) without forgetting the the cost of using aspirator (C_furnace) calculated by the following relation:

$$C_{heat\ treatment} = t_{heat\ treatment} \times (C_l + C_{furnace})$$

3.10. Cost of machine per part

To determine the cost of an SLM machine per part, we must first determine the machine's useful life (Y_life). The machine cost is estimated to be roughly 5.000.000 MAD, which is the SLM machine's investment cost. The machine's use can thus be regarded 5 years based on its usual depreciation time, according to Lindemann et al. In one year, the machine is used for approximately 5000 hours, and the total machine utilization over the five years can be considered to be 25 000 hours, as indicated in the equation bellow.

$$machine\ useful\ life = 5years \times 5000\ h = 25\ 000\ h$$

As a result, the cost of machine per part is obtained, as shown in equation is:

$$\frac{C_{purchase} \times T_{build}}{N \times 0.9Y_{life}}$$

4. Case study

The most straightforward way to demonstrate the cost-effectiveness of Selective Laser melting is to use case studies. This present cost estimation analysis will evaluate the economic aspect of selective laser melting. Based on the cost estimation method studied in previous sections, this case study consists of manufacturing of a cubic crane, the 3D model shown in figure 3 below (20x20x20) mm and the material used is stain less steel 316L.

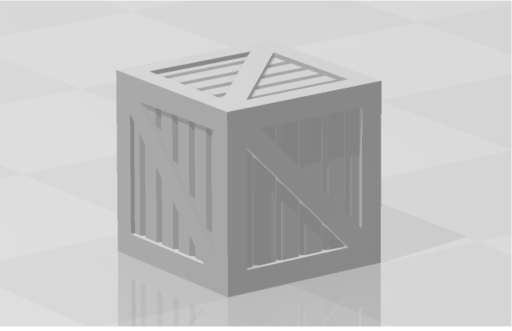

Figure 5. 3D model of cubic crane used in the case study

4.1. Material

The stainless steel 316L is a material used to produce many products such as Heat exchangers, jet engine parts, valve and pump parts, chemical processing equipment, tanks, and evaporators, which has superior corrosion resistance and is stronger at high temperatures. The chemical composition is shown in table 2 below. During the construction process, the powder is melted into 30 µm thick layers. 316L stainless steel is widely utilized in aerospace, medical, and other engineering applications that require strong corrosion resistance and strength. Spare components, small series items, functioning electromechanical systems, and customized products can all be made with stainless steel 316L.

Table 3. powder stainless steel chemical composition

Element	Concentration wt.%
C	0,030
Cr	18,00
Cu	0,50
Fe	Balance
Mn	2,00
Mo	5,5
N	0,10
Ni	13
O	0,10
P	0,025
S	0,010
Si	0,75

4.2. Machine

A Nd:YAG laser (Neodymium-doped yttrium aluminum garnet) with a wavelength of 1070+-10 nm is utilized in this experiment. A fiber transports the laser beam to the scanner optical system, which is subsequently delivered to the machine chamber using the SCANLAB scanner. The laser beam is a continuous laser wave with a focus point size of roughly 70um (CW).
Ep-M250 is the name of the research machine, which is housed in Abdelmalek Essaadi University's Faculty of Sciences and Techniques of Additive Manufacturing Laboratory. Scanner, laser source, selective laser melting, and chamber divided into four basic components: powder feed storage container, building part platform, recycled powder storage container, and recoating system.

Table 4. SLM EP250 machine specification

Feature	SLM EP250
Machine Type	Selective Laser Melting
Rated electrical power	6 kW
Maximum Scan Speed	8 m/s
Laser Power	500 W

The SLM machine was used to perform selective laser melting of a cubic crane with a layer height of 30 µm and a stainless-steel powder 316L as the metal powder material. After satisfying the process requirements, this powder was sieved manually ant heated up with over for 24 h at 80 °C. The powder container was then transported to the SLM machine after sieving. The SLM machine was turned on at the same time, and the necessary basic settings were completed. The room was inundated with nitrogen inert gas and the platform was heated. Before beginning the printing operation, the chamber was preheated for 2 hours, and the platform was kept at 60 °C during the fabrication.

5. Results and discussions

A cost model was created utilizing a spreadsheet and an automated technique in this investigation. The model can do a cost estimating study using an approach that is both precise and decisive. The cost model produced was based on an estimate of all costs associated with each SLM process phase. The consumed quantity of material (kg), the machine preparation, and the process build time were the major factors included in the model (hours). The primary factors utilized to build the cost model are broken down in Table 7.

According to the equation

$$\frac{C_{purchase} \times T}{N \times 0.9Y_{life}}$$

With T is the time for using the machine for our part and because we study one part N=1 and the Y_life is as given before 25 000 h. Table 7 Shows the rate cost of every machine and number of hours spent at every task

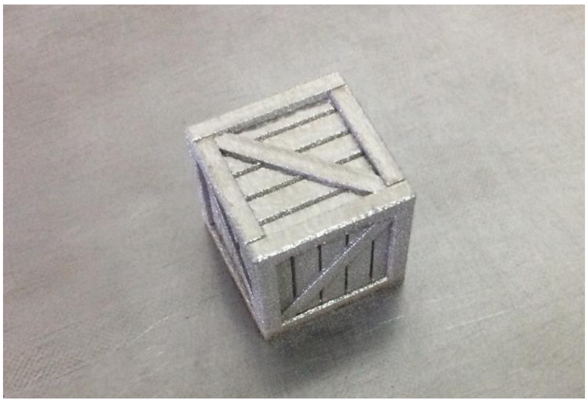

Figure 6 Cubic crane fabricated using Selective laser Melting

The majority of these assumptions were discussed before. Based on the cost model developed in this study, the material and thermal treatment prices were established. The Stainless steel 316L was the material under consideration. rate and labor cost were calculated using data from the Moroccan literature.

Table 5 labor rate and material per Kg price

Task or equipment	**Cost**
Labor cost rate	40 MAD/h
Material price	1000 MAD/Kg

Table 6. Costs and cost structure of the Crane test build

Machine	**Purchase cost (MAD)**	**Rate cost per hour (MAD)**	**Machine rate and labor (MAD)**	**Time of use(H)**
SLM machine	5 000 000,00	1 777,78	2 130	8
Band Saw	50 000,00	2,22	46	1
Furnace	70 000,00	9,33	141	3
aspirator	20 000,00	1,78	90	2
CAD software	100 000,00	22,22	242	5
Buil plan software	100 000,00	13,33	145	3
oven	30 000,00	32,00	76	24
gaz supply	400 000,00	213,33	257	12
Milling rectification		200,00	288	2
Material			120	
labor cost		40		
total Cost	**3 536 MAD**			

The table shows cost structure for the crane test build fabricated with the Selective Laser melting, it demonstrates also the time for building and for using every machine related to the building of the part

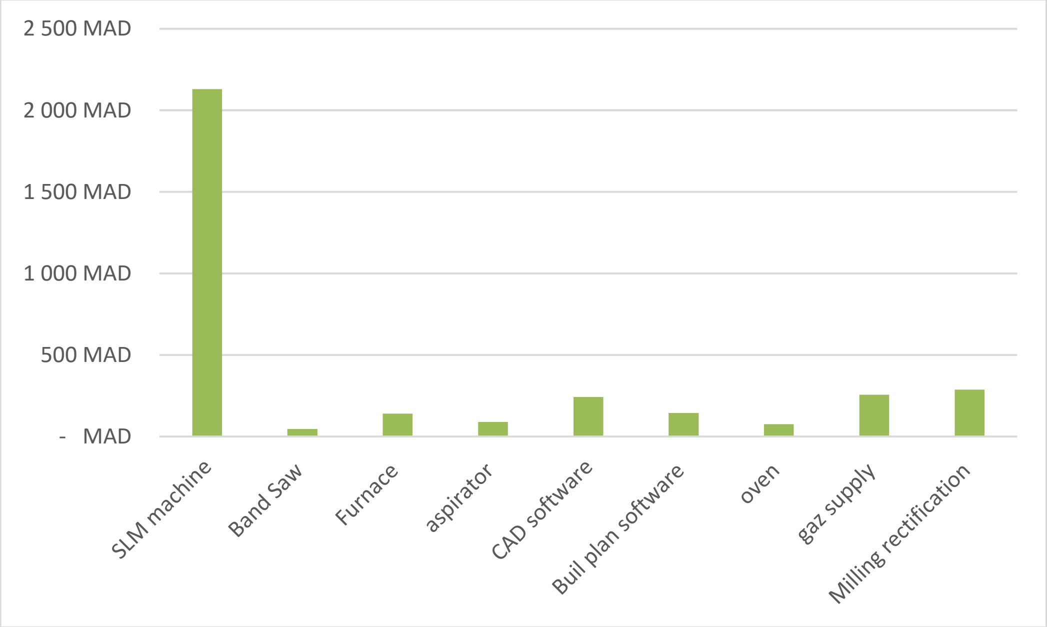

Figure 7 costs for building the test crane with SLM

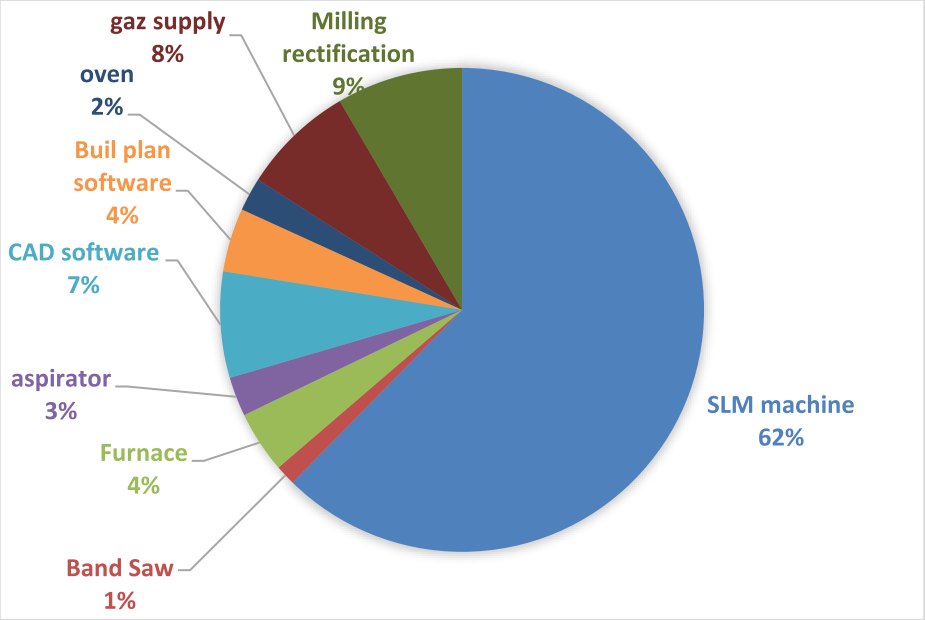

Figure 8 cost percentage for building test crane with SLM

As a result of the calculations of costs for each process step in the cost model, an estimation of final cost for a SLM technology has been made possible by establishing or defining the primary variables listed in the current cost model.

In this initial test, the overall cost of a SLM process with a part that mesurs (2cmx2cmx2cm) came to 3536 MAD As indicated in Table7, the four major contributors account for approximately 85 percent of the overall cost. The machine cost was by far the largest factor in Selective Laser Melting, followed by the post processing cost to 9% for operation such as rectification and milling the substrate

the designer cost can also play a significant role. As the designer is capable of generating without regard to production constraints. Build planning was also an important cost driver (4 percent). While the construction process is almost labor-free, the build preparation is not. In reality, machine preparation, as well as data preparation, are two of the most labor-intensive operations because they demand a highly qualified and experienced specialist. To arrange the parts in the building chamber and produce the CAD file, knowledge is required. Nonetheless, the time invested in this stage of preparation is significant, which has an impact on the associated cost.

6. Conclusion

The evolution of cost models is critical in modern production environments due to the continual growth of overhead costs. Selective Laser Melting, in particular, is made up of a number of innovative manufacturing processes that must be assessed economically and compared to other manufacturing systems. A more realistic cost model for Selective Laser Melting is presented in this paper, which is based on the activity method and includes all processes of manufacturing using SLM, such as part design and post processing, such as heat treatment, among other things. This investigation allows us to gain a comprehensive understanding of the complete value network of Selective Laser Melting. We identified eight process phases for a generic AM process in this paper. The cost estimator described in this work is based on the concept of total costing which covers labor, materials, machine, production, and administrative overheads. On a machine working-time basis, the indirect costs were ascribed to the components. The key result obtained is the cost per part. The machine cost per part and the post processing are the primary contributors to the costs of a SLM process, according to the cost analysis. The machine cost per part is the largest, followed by the post processing cost. This study revealed that both machine and post processing costs have a significant impact on the total cost of a SLM process, and that they can entirely modify it. A case study was experimented by using the SLM machine EP 250. the cost resulted developed by this model compared with quotation from international company in the field of AM was similar to fabricate the Cubic crane as a result the cost model can be used to estimate every part fabricated with the SLM machine.

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