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Establishment of a Teaching Foundry Workshop at the National Pedagogical University

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***Abstract*—*This study explores the feasibility of establishing a teaching foundry workshop at the National Pedagogical University (UPN) to enhance students' practical training in mechanics, metallurgy, and applied sciences. The research stems from the observation that foundry work, despite its importance in several industrial sectors, including automotive, mechanical engineering, energy, and maintenance, remains underdeveloped in higher education institutions in the Democratic Republic of Congo. The study compares several casting processes and selects sand casting as the starting method due to its simplicity, educational value, and ability to make the various manufacturing stages directly observable. Aluminum or its alloys are preferred as the initial material, and an electric crucible furnace with a capacity of approximately 15 to 30 kg per casting is proposed. The crankshaft is chosen as the training piece because its geometry allows for the practical study of mold filling, solidification, shrinkage, and casting defects. The proposed teaching process includes model design, sand and mold preparation, aluminum melting, casting, solidification, cooling, shakeout, deburring, and final inspection. The workshop must also incorporate measuring and control equipment as well as personal protective equipment, given the thermal, mechanical, respiratory, and electrical hazards associated with foundry operations. The proposed spatial organization follows a logical flow from storage to sand preparation, molding, melting, casting, cooling, shakeout and deburring, then inspection and removal. This organization aims to improve safety, limit the movement of molten metal, and prevent haphazard crossings between the flows of materials, parts, and people.*

***Keywords*—** *Didactic foundry; National Pedagogical University; sand casting; aluminum; crankshaft; mechanical manufacturing; practical training; workshop setup.*

I. INTRODUCTION

The National Pedagogical University (UPN), as an institution training engineers and teachers in the technical field, must absolutely equip itself with suitable infrastructures to offer its students concrete and directly applicable training.

The foundry sector, though essential in many industrial sectors such as automotive, general mechanics, and energy, remains largely untapped in higher education institutions in the Democratic Republic of Congo (DRC). Yet, mastery of this technology is crucial for training technicians capable of meeting the needs of local and regional industry.

In this context, the establishment of a teaching foundry at the National Pedagogical University (UPN) is essential not only as a pedagogical lever, but also as a strategic opportunity for developing local skills.

The manufacture of complex mechanical parts, and particularly automotive parts used in internal combustion engines, was chosen for this study because it illustrates the potential and technical requirements of such an infrastructure.

Among the fundamental technologies in the field of mechanics and manufacturing, foundry work occupies a strategic position. It enables the design of complex parts from molten metals, with direct applications in the automotive, machine construction, and industrial maintenance sectors.

Despite its importance, this discipline is underdeveloped in the educational curricula at UPN, mainly due to a lack of practical facilities.

However, the implementation of such a system requires a rigorous study, integrating technical, educational, economic and logistical dimensions.

With this in mind, the study proposes the manufacture of various mechanical parts (car parts and parts of various industrial machines), the manufacture of which in a didactic context offers multiple educational advantages: moderate complexity, representative molding process and industrial relevance.

Thus, a key question arises:

- Is it possible to set up a foundry workshop at the National Pedagogical University (UPN) for the manufacture of various mechanical parts?
- What material, human, and financial resources are needed to establish a teaching foundry workshop at UPN?

The establishment of a didactic foundry workshop at UPN is possible and justified, both from a pedagogical and economic point of view;

UPN has certain prerequisites (infrastructure, human resources, institutional will) that can facilitate the installation of a teaching foundry;

The objectives of this research are:

- Evaluate the feasibility of establishing a teaching foundry workshop at UPN through the study of mechanical parts manufacturing
- Identify the technical, material and human needs for setting up the foundry workshop;
- To study the steps in the manufacturing process of a model part in a didactic context;
- Propose a preliminary site plan, taking into account constraints and opportunities;
- Select the appropriate machines and equipment for use in the foundry workshop.

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To conduct this research, we used the analytical and comparative method. To these methods, we added documentary and interview techniques.

II. THEORETICAL FRAMEWORK ON THE FOUNDRY

Casting is one of the oldest and most widely used manufacturing processes in the fields of metallurgy and mechanical engineering. It involves producing metal parts by melting a metal or alloy and then pouring it into a mold that reproduces the desired shape. After cooling and solidification, the resulting part can undergo various finishing operations to meet technical and dimensional requirements (Campbell, 2015).

Thanks to its ability to produce complex and large parts, the foundry plays a fundamental role in several industrial sectors. (Groover, 2020).

II.1. Definition of a foundry

According to Bruce Anglade (2018), in his work on the Metal Forming Process, casting consists of pouring a metal or alloy in a liquid state into a mold to reproduce a part in its internal and external shapes, minimizing finishing work after cooling. Used in various sectors (aeronautics, automotive, plumbing fixtures, household appliances, etc.), the techniques depend on the material, the dimensions and geometric characteristics of the part to be produced, as well as the quantities to be manufactured.

II.2. Types of foundry

Foundries can also be classified according to the type of metal they produce, i.e., ferrous or non-ferrous. There is a significant difference between a zinc foundry producing a large series of toy car chassis and an iron foundry producing rotor housings for wind turbines.

II.3. Some basic concepts

The principle of foundry work is to pour an alloy into a mold. The pouring temperature depends on the type of alloy used; for example, zinc alloys are heated to 400°C, aluminum alloys to 700°C, copper alloys to 1250°C and ferrous alloys to 1550°C.

Cooling leads to solidification and the production of the raw or finished part. In a foundry process, three classes of problems arise.

- to make the mold;
- pour the part;
- extract the part.

A foundry process corresponds to the resolution of these three problems

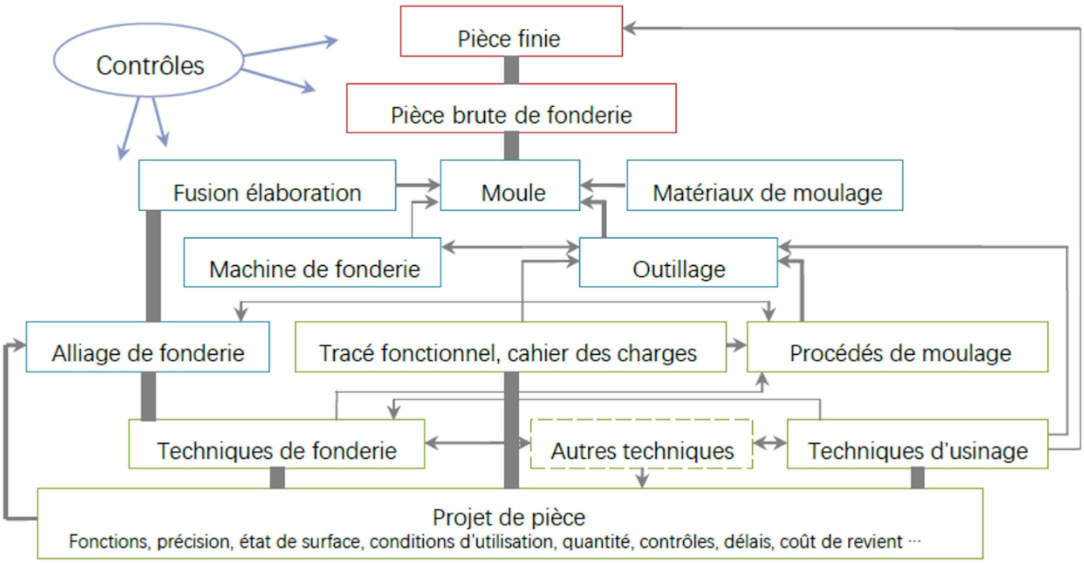

Figure 1.1: Diagram of the design to production of a foundry part [Fédération Forge Fonderie (2016)].

II.4. Industrial importance of the foundry

The foundry plays a vital role in modern industry, as it enables the manufacture of numerous components essential to the operation of industrial equipment and mechanical machinery. It makes a significant contribution to the development of the mechanical engineering, transportation, energy, and industrial maintenance sectors.

The foundry offers several industrial advantages, including the ability to produce complex parts, the reduction of manufacturing costs for certain productions, and the valorization of recycled metals (Campbell, 2015).

It also constitutes a strategic sector in the technological and industrial development of a country by promoting the local processing of metallic raw materials.

II.5.1. Training Workshop

The training workshop plays a central role in technical and vocational training, as it provides a unique space where theoretical knowledge is put into practice through hands-on, practical activities. It allows learners to acquire technical skills, develop practical abilities, and become familiar with the equipment, tools, and work methods used in industry.

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II.5.2. Types of foundry processes

Casting processes can be classified according to the type of mold used, the method of filling the molten metal, and the level of precision required. Each process has specific technical characteristics adapted to particular industrial needs. The choice of process generally depends on the shape of the part, the material used, the manufacturing cost, and the desired production quantity. In both industrial settings and educational workshops, certain processes are preferred due to their simplicity, lower cost, or ability to produce high-precision parts. Here are some types of casting:

- Sand foundry
- Shell Foundry
- Pressure die casting

II.6. Didactic Foundry

The teaching foundry provides a training environment designed to enable learners to acquire the knowledge and skills necessary to master the processes of manufacturing metal parts by casting. It represents an educational adaptation of the industrial foundry, whose primary objective is not large-scale production, but rather teaching the various stages of the manufacturing process in a safe and supportive learning environment. According to Campbell (2015), casting is a manufacturing process that consists of obtaining metal parts by pouring molten metal into a mold shaped like the part to be produced.

II.7. Concept of implantation

Implementation refers to all the operations involved in setting up infrastructure, equipment, or a system for operation within a given environment. It is a strategic step requiring rigorous planning, appropriate organization, and the effective mobilization of human, material, financial, and technical resources. According to Slack, Brandon-Jones, and Johnston (2022), implementing an industrial facility involves not only installing equipment but also organizing spaces, workflows, resources, and activities to ensure efficient and sustainable operation.

III. TECHNICAL FEASIBILITY STUDY

The technical study aims to determine whether the proposed technological choices are compatible with the workshop's academic purpose. The key finding is that the planned foundry must be a small-scale educational facility, not a large-scale industrial foundry. This distinction influences the process, equipment capacity, space organization, and maintenance requirements.

Several processes are possible: sand casting, shell casting, lost-wax casting, pressure casting, low-pressure casting, and special processes. A comparison shows that sand casting offers the best compromise for initial implementation. It allows students to work on the model, the sand, the parting line, the vents, the feed dogs, the risers, the pouring, the shakeout, and the deburring.

Critère	**Moulage au sable**	**Coquille**	**Cire perdue**	**Sous pression**
Coût	Faible à moyen	Moyen à élevé	Moyen	Très élevé
Complexité	Faible à moyenne	Moyenne	Moyenne à élevée	Très élevée
Sécurité	Maîtrisable	Maîtrisable	Élevée	Très élevée
Valeur pédagogique	Très élevée	Élevée	Élevée	Élevée mais industrielle
Position proposée	Phase 1	Phase 2	Module avancé	Non prioritaire

III.1.2. Comparison and choice of process

Sand casting is chosen because it makes the relationship between design and manufacturing visible. The model must incorporate casting corrections, including machining allowances, shrinkage, draft angles, and elements of the casting system. The mold must then reproduce this geometry while allowing for gas venting and proper feeding of the part.

This choice is particularly relevant for the educational crankshaft. Its geometry includes arms, bearing surfaces, crankpins, changes in cross-section, and areas that can become hot spots. These features provide students with concrete situations to understand the problems of filling, solidification, and shrinkage.

Aluminium was chosen for the initial applications. The documents provided presented it as a suitable material for a university foundry due to its relatively low melting point, its availability as recyclable scrap, its good castability, and its suitability for studying foundry defects.

Starting process: sand molding.

Preferred material: cast aluminum or aluminum alloy.

Oven chosen: electric crucible oven.

Training piece: crankshaft.

Possible evolution: shell, lost wax, characterization, simulation and additive manufacturing.

III.1.2. Pedagogical justification for the choice

The purpose of a university foundry is not solely to produce parts. It is to create learning situations in which students can observe, manipulate, measure, compare, and explain. The choice of sand casting facilitates this approach because the operations are accessible and directly observable.

The crankshaft reinforces this educational value. It is not a simple geometry: the variations in cross-section and the massive areas allow for the study of defects associated with solidification. The student can thus relate the shape of the part to the choices of the feeding system, and then compare the hypotheses with the actual part produced.

Étape	**Compétence mobilisée**	**Résultat observable**
CAO et modèle	Conception pour la fonderie	Modèle corrigé
Moulage	Préparation du sable et empreinte	Moule exploitable
Fusion	Contrôle du bain métallique	Métal liquide conforme au procédé
Coulée	Maîtrise de l'opération	Remplissage de l'empreinte
Décochage	Observation des défauts	Pièce brute
Ébarbage	Parachèvement	Pièce nettoyée
Contrôle	Métrologie et diagnostic	Fiche de résultats

III.1.3. General crankshaft manufacturing process

The proposed process is organized as a continuous chain. The design of the model constitutes the starting point. This is followed by the preparation of the sand and the mold, the melting of the metal, the casting, the solidification, the

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cooling, the demolding, the deburring, any necessary treatments and finally the inspection.

The chosen principle is that of a pedagogical progression. Each step must be accompanied by a practical work sheet allowing for the recording of the conditions under which it was carried out and observations. The results of this work will then be used to improve the corresponding step.

N°	Opération	Question pédagogique principale
1	Conception du modèle	Comment adapter la géométrie aux contraintes de fonderie ?
2	Préparation du moule	Comment obtenir une empreinte résistante et perméable ?
3	Fusion	Comment contrôler la température et la propreté du bain ?
4	Coulée	Comment remplir l'empreinte sans défaut majeur ?
5	Solidification	Comment maîtriser le retrait et les points chauds ?
6	Décochage	Quels défauts sont visibles sur la pièce ?
7	Ébarbage	Comment obtenir une pièce brute propre ?
8	Contrôle	Quels écarts existent entre modèle et pièce ?
9	Correction	Quelle modification faut-il apporter au procédé ?

III.1.4. Development of the model and the mold

The crankshaft model represents the intermediate step between the design and the finished part. The documents studied indicate that it must incorporate casting-specific corrections: metal removal, draft angles, machining allowances, parting line, vents, feed points, and the feed system. A model error will affect the mold and then the finished part.

The model can be made of wood, resin, 3D-printed polymer, or lightweight metal. From a modernization perspective, CAD and rapid prototyping allow for a direct link between the digital model and the physical model. 3D printing can thus be gradually introduced into the methods department.

Mold preparation relies on sand casting. The sand must have sufficient cohesion and permeability. It must also be prepared and tested. Mixing, sieving, moisture control, and simple tests then become educational activities.

III.1.5. Aluminum smelting

Melting is the first operation in the hot zone. The electric crucible furnace is chosen for the first phase. Source documents suggest a capacity of approximately 10 to 30 kg of aluminum, sufficient for training pieces, test specimens, and casting demonstrations.

Élément	Fonction	Interprétation
Four électrique à creuset	Fusion	Équipement central de la phase 1
Creuset	Contenir le métal liquide	Doit être adapté et surveillé
Pinces	Manutention	Réduire le risque de chute
Louche	Transfert vers le moule	Trajet court et dégagé
Pyromètre	Mesure de température	Relier température et qualité
Écumoire	Retrait des scories	Améliorer la propreté du bain

The metal load must be sorted, cleaned, and prepared. Scrap can be used for recycling, but materials containing paints, oils, impurities, or unknown compositions must be discarded. This preparation directly impacts bath quality and safety.

Temperature control is essential. Insufficient temperature can lead to improper filling, while excessive temperature can promote oxidation and gas absorption. A pyrometer or a suitable probe therefore becomes both a teaching tool and a monitoring instrument.

III.1.6. Pouring, solidification and cooling

Pouring is the process by which molten metal is transferred from the crucible to the mold. The consistency of this operation is crucial. Pouring too quickly can increase turbulence, while pouring too slowly can lead to premature cooling and poor filling.

For the crankshaft, differences in cross-section must be carefully observed. Thin sections can solidify quickly, while thicker areas remain liquid longer. These latter areas can become critical zones with respect to shrinkage cavities.

Solidification results in volumetric shrinkage. The role of the risers is therefore to supply the areas that solidify late. The vents, for their part, facilitate the evacuation of gases from the mold. The observed defects should be used as experimental results.

III.1.7. Possible heat treatments

Heat treatment is not essential for all parts in the first phase, but it represents a potential development option. For a suitable aluminum alloy, it can be used to study stress relieving, aging, or other thermal effects depending on the desired properties.

The educational value lies in comparing two specimens from the same casting: one preserved in its raw state and the other having undergone a thermal cycle. Hardness, structure, and mechanical behavior can then be compared if the necessary equipment is available.

Phase	Équipement associé	Finalité pédagogique
1	Four de fusion	Comprendre fusion et coulée
2	Four de traitement thermique	Relier température et propriétés
2	Duromètre	Comparer les états de matériau
2	Métallographie	Observer la microstructure
3	Essais mécaniques	Relier procédé et propriétés

III.1.8. Dimensional and mechanical controls

The final inspection transforms manufacturing into an experimental process. The first level is visual: surface finish, burrs, cracks, material deficiencies, inclusions, visible porosity, demolding defects, and roughness. The second level is dimensional and allows comparison of the part to the model or drawing.

For the crankshaft, the dimensions of interest include the bearing diameters, center-to-center distances, lengths, arm thicknesses, and overall alignment. The instruments used include calipers, a micrometer, a dial indicator, a surface plate, and, if available, a profile projector.

Niveau	Moyens	Données
Visuel	Observation directe	Défauts de surface
Dimensionnel	Pied à coulisse, micromètre, comparateur	Dimensions et écarts
Sables	Tamis, étuve, balance	Humidité et granulométrie
Mécanique	Duromètre, machine de traction	Dureté et résistance
Microstructural	Polisseuse, microscope	Structure et défauts

III.2. Necessary equipment and facilities

Analysis of the equipment shows that the furnace is only one element of a larger system. The workshop must bring

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together the means for preparation, molding, melting, casting, cooling, demolding, finishing, control and safety.

Famille	Équipements principaux	Priorité
Fusion	Four à creuset, creusets, louches, pinces, pyromètre	Phase 1
Moulage	Châssis, tables, fouloirs, truelles, tamis, malaxeur	Phase 1
Sécurité	EPI, extincteurs, sable sec, signalisation, extraction	Phase 1
Contrôle	Pied à coulisse, micromètre, balance, duromètre	Phase 1-2
Caractérisation	Étuve, polisseuse, microscope, essais mécaniques	Phase 2
Numérique	CAO, imprimante 3D, simulation	Phase 2-3

This prioritization is an important outcome. It avoids concentrating investment on sophisticated equipment before the fundamental operations are mastered. The first phase must ensure the basic chain is fully operational.

III.2.1. Safety equipment

Safety is a prerequisite for operation, not an afterthought. Melting, casting, shakeout, and deburring operations present thermal, mechanical, respiratory, electrical, and organizational risks.

PPE includes, among other things, goggles or a face shield, suitable gloves, safety shoes, apron or heat-resistant jacket, appropriate clothing, respiratory protection when required, and hearing protection in noisy areas.

Risque	Source	Moyen de maîtrise
Brûlure	Four, métal liquide, moules	Balisage + EPI thermiques
Projection	Humidité, coulée	Outils et moules secs
Fumées/poussières	Fusion, décochage, ébarbage	Ventilation et extraction
Coupure	Sciage, meulage	EPI et zone séparée
Manutention	Châssis, creusets, sable	Chariots, pinces, supports
Électricité	Four, malaxeur, outils	Inspection et maintenance

III.2.2. Control and measurement tools

Control instruments enable the transition from manufacturing to experimental engineering. They must be protected from dust, heat, and shocks and stored in a clean area.

Contrôle	Équipement	Utilité
Thermique	Pyromètre / thermocouple	Température de fusion et coulée
Dimensionnel	Pied à coulisse / micromètre	Écarts et retrait
Géométrique	Comparateur / marbre	Alignement et forme
Sable	Tamis / étuve / balance	Propriétés du matériau de moulage
Dureté	Duromètre	Comparaison des états
Microstructure	Polisseuse / microscope	Effet de la solidification

III.3. Spatial layout of the foundry

The spatial layout constitutes the physical translation of the process. The principle adopted is a linear or semi-linear flow allowing the material to enter, progress through the operations and then exit as a controlled part.

The main areas identified are: storage, sand preparation, molding, melting, casting, cooling, deburring, finishing, and inspection. Additional areas are also planned: workshop manager's office, assistant workshop manager's office, methods office, and design office.

Zone	Fonction	Position logique
Stockage	Matières, modèles, EPI	En amont du procédé
Préparation sable	Malaxage et tamisage	Avant moulage
Moulage	Empreinte et alimentation	Après préparation
Fusion	Production du métal liquide	Zone isolée
Coulée	Remplissage du moule	Près du four
Refroidissement	Attente des moules chauds	Après coulée
Décochage/ébarbage	Libération et finition	Après refroidissement
Contrôle	Mesure et diagnostic	Zone propre

III.3.2. Functional layout diagram

The proposed functional diagram can be represented textually as *follows*:

STORAGE → SAND PREPARATION → MOLDING → MELTING → POURING → COOLING → ROCKING / DEBURGING → INSPECTION → EXIT

The diagram should not be interpreted as a simple geometric line. Actual distances must be adapted to the available space, access points, ventilation, emergency exits, and handling constraints. The fundamental principle, however, remains the continuity of the flow.

The pouring area must be very close to the furnace to minimize the transport distance of the molten metal. The inspection area must be away from heat, dust, and vibration. The shakeout area must be separate from the clean casting area.

III.3.3. Movement of equipment and people

Three flows must be distinguished: cold materials, hot parts or parts in the process of being manufactured, and people. These flows must not intersect haphazardly. The flow of liquid metal is the most critical and must be reduced to the bare minimum.

Flux	Trajet	Risque	Mesure
Matières froides	Stockage → préparation	Encombrement / humidité	Bacs identifiés
Sable préparé	Préparation → moulage	Mélange avec sable usé	Séparation des stocks
Moules	Moulage → coulée	Choc / rupture	Trajet court
Métal liquide	Four → moule	Projection / brûlure	Zone interdite et trajet dégagé
Moules chauds	Coulée → refroidissement	Brûlure	Balisage
Déchets	Décochage → tri	Poussières / encombrement	Bacs séparés
Étudiants	Circulation périphérique	Exposition	Groupes limités

Sources of funding and sustainability

Several funding sources are possible: university budgets, industry partnerships, institutional support, international cooperation, and limited services. Diversification is important to avoid the workshop becoming dependent on one-off funding.

Source	Contribution possible	Condition
Budget universitaire	Équipements de base, local, personnel	Intégration au programme académique
Partenariats industriels	Rebuts, stages, expertise, équipements	Convention claire
Institutions publiques	Subventions et modernisation	Dossier technique solide
Coopération	Formation, équipements, expertise	Projet structuré et durable
Prestations limitées	Petites pièces pédagogiques	Rester secondaire à l'enseignement

Proposed phased implementation

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Phase	Contenu	Objectif
Phase 1	Four à creuset, moulage manuel, sable, EPI, ventilation, métrologie simple	Démarrer les TP
Phase 2	Caractérisation des sables, métallographie, essais mécaniques, machines-outils	Renforcer l'expérimentation
Phase 3	CAO avancée, impression 3D, simulation, contrôles avancés	Moderniser et optimiser

The first phase must make the workshop immediately operational. It must allow for the preparation of the sand, the making of the molds, the melting of the aluminum, the casting, the cooling, the demolding, the deburring and the dimensional control.

The second phase must delve deeper into the relationship between process, structure, and properties. Characterization equipment then allows the workshop to be transformed into an applied metallurgy laboratory.

The third phase can incorporate more digital tools. CAD, 3D printing, and simulation make it possible to link digital design and actual manufacturing. They also offer opportunities to optimize the model and the casting system.

This progression avoids confusing scientific ambition with the need for initial setup. It allows UPN to adapt the workshop's development to its resources, staff training, and the actual number of users.

IV. Conclusion

The main objective of this study was to assess the feasibility of establishing a foundry workshop for educational purposes, enabling students to master the main operations involved in manufacturing metal parts. To achieve this objective, we studied the fundamental principles of foundry work, the various molding processes, the materials used, the necessary equipment, and the requirements related to the organization, safety, and operation of a workshop.

From a technical standpoint, sand casting combined with aluminum melting was chosen as the starting process. This choice was justified by its ease of implementation, its educational value, and the possibility of adapting the equipment to the needs of a university workshop. The crankshaft was chosen as the model part because its geometry allows for the illustration of several phenomena and operations specific to the manufacturing of mechanical parts by casting.

The study also identified the main equipment needed, including a crucible furnace with a capacity of 15 to 30 kg per casting, molding and sand preparation tools, measuring and control instruments, and personal protective equipment. The proposed spatial organization takes into account the logical sequence of operations, from material preparation to inspection of the finished part.

Furthermore, the establishment of such a workshop cannot be limited to purely technical aspects. It also requires the availability of qualified personnel, a suitable educational organization, strict safety measures, appropriate ventilation, fire-fighting equipment, a maintenance program, and financial resources to ensure its sustainable operation.

V. References

[1] CAMPBELL, J. (2015). Complete Casting Handbook: Metal Casting Processes, Metallurgy, Techniques and Design. 2nd ed. Oxford: Butterworth-Heinemann.
[2] GROOVER, MP (2020). Fundamentals of Modern Manufacturing: Materials, Processes, and Systems. 7th ed. Hoboken: John Wiley & Sons.
[3] KALPAKJIAN, S. and SCHMID, SR (2014). Manufacturing Engineering and Technology. 7th ed. Pearson.
[4] ASM INTERNATIONAL. (1998). ASM Handbook, Volume 15: Casting. Materials Park, Ohio: ASM International.
[5] BEELEY, P. (2001). Foundry Technology. 2nd ed. Oxford: Butterworth-Heinemann.
[6] JAIN, PL (2003). Principles of Foundry Technology. 4th ed. New Delhi: Tata McGraw-Hill.
[7] RAVI, B. (2005). Metal Casting: Computer-Aided Design and Analysis. New Delhi: PHI Learning.
[8] CAMPBELL, J. (2003). Castings. 2nd ed. Oxford: Butterworth-Heinemann.