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CONTENT

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GANTT CHART AS A PROJECT MANAGEMENT TOOL THAT REPRESENTS A CLUTCH HUB MANUFACTURING PROCESS

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Abstract. The purpose of the research in this paper is to present a clutch hub manufacturing process via Gantter, a Gantt chart-based project management software. The Gantt chart is one of the most used planning and controlling tools in project management today and it can be called the main and very important tool for management. It allows the creation and edition of project plans through the implementation of defined activities, their durations, relationships between the activities, appropriate resources, and possible risks. This paper is an example that shows how the logic embedded in projects can be based on real manufacturing processes and applied to a project management tool in order to achieve the goals of the project.

1. Introduction

Numerous individuals as well as organizations have provided definitions of what a project is or should be, but the definition given in BS 6079-2:2000 Project Management Vocabulary is probably the most authoritative one. According to the vocabulary, a project is: "*A unique process, consisting of a set of co-ordinated and controlled activities with start and finish dates, undertaken to achieve an objectives conforming to specific requirements, including constraints of time, cost and resources*." [10]

The management of a certain project, also known as project management, generally refers to the application of knowledge, skills, tools, and techniques applied to project activities in order to accomplish the project requirements. It is a process that includes planning, putting the plan into action, and measuring the progress and performance of the project. [17]

An *activity* is a project component, according to project managers, that takes time to complete. Resources may or may not be necessary. Usually, an activity takes up time, either as people wait or while they work. To complete the activities in a project, resources are required. They can be any of the definable resources (typically something other than labor) required to complete a project activity and include people, equipment, facilities, funding, etc. Any project features a number of components that can be scheduled, estimated, and easily monitored and controlled. [9,17]

The project success is correlated with achieving the project goals within the project timeline. The success of the project is connected to milestones, such as significant events in the project, that consume no time or resources. They usually signify the completion of a major phase of the work. Reaching each major project milestone contributes to more easily measured progress in the realization of the project. Milestones are implemented to increase the project`s work and focus in order to maintain the project on schedule and

Keywords. Resource, risk, schedule, manufacturing operation, machine.

prevent delays related to risk and hard decisions. Risks appear in each project as the possibility that something will happen during the realization of the project and will have a negative impact on achieving project goals. [2, 6]

To illustrate a project and the activity relationships in the project, the Gantt chart is often applied. The Gantt chart, commonly known as a bar chart, is a time-scaled graphic that displays each activity with a bar that shows the duration, start, and finish time of the activity. It is easy to read when presenting sufficient information about the activities within a short time frame. The key concept in the Gantt chart is the tool for milestones used to mark the achievement of specific points along a project timeline, functioning as an indicator of progress in the project. [2, 4]

The Gantt Chart is one of the most used tools for planning and controlling projects in project management today. In a survey involving 750 project managers, the Gantt Chart was the fourth most-used tool among 70 tools and techniques related to project management (Besner & Hobbs, 2008). It is hard to imagine project management without the Gantt Chart because it is part of the connection among the members of the project management community. [3]

In this paper, a manufacturing process presented via a Gantt chart is illustrated. It is divided into four sections. After the introduction, in the second section, the manufacturing process is explained in detail. In the third section, the created Gantt chart is discussed, and in the fourth section, a conclusion and a potential application of the research are presented.

2. Research

This research relates to the project management clutch hub manufacturing process for a production line of 100 clutch hubs with catalog number 4305.32.26.

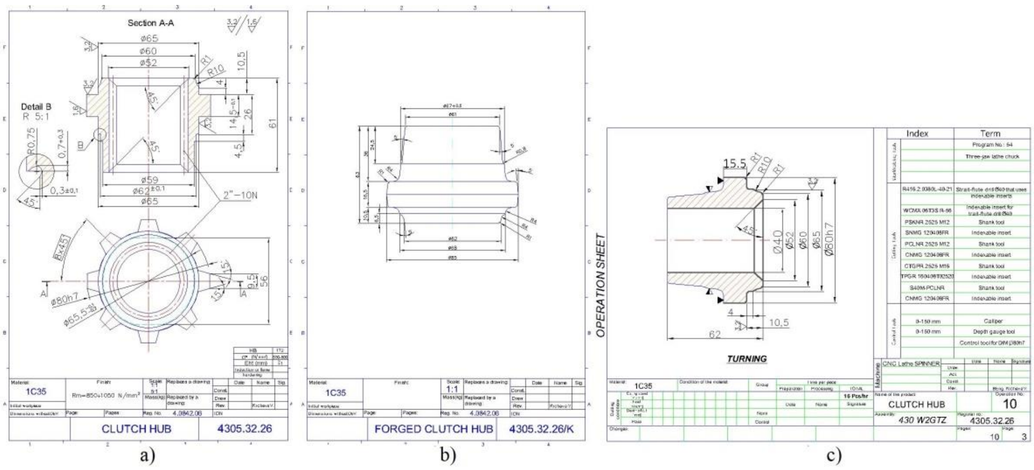


Figure 1. *(a) Clutch hub, (b) Forged clutch hub, (c) Turning operation*

The technological procedure is designed via AutoCAD software and includes several manufacturing operations. The sequence of the operations intended to be realized composes the schedule of the process. To visually represent the schedule of the process, a horizontal bar chart implemented in project management is used. It displays the manufacturing operations in the role of activities that make up the project, their duration, start date, and finish date.

The manufacturing operations (in the role of activities) and the manufacturing process (in the role of a project) are described in the following part. The information about the activities, norms, corresponding resources, and working hours for each activity is contained in the AutoCAD drawing, shown in the appropriate figures.

- *Activity 1: Transportation of forged clutch hubs from the warehouse;*

The starting workpiece used to produce the clutch hub (Fig. 1a) is the forged clutch hub (Fig. 1b). The forged clutch hubs are produced in the Forging department according to the predefined construction drawing and technology. Their production is planned in advance, in large quantities, because these forged clutch hubs are the starting workpieces for making not only specified clutch hubs (4305.32.26) but also other clutch hubs of similar dimensions. One of the differences may be the profile of the shaft of the vehicle, for which the clutch disc is intended (in whose assembly the hub itself is included). So, from the same forged clutch hubs, different final clutch hubs are obtained, with different profiles, for suitable vehicles. Therefore, the production of forged clutch hubs does not appear as an activity for the production of the final clutch hubs (4305.32.26) but represents a pre-planned and realized process. Starting workpieces are available in the warehouse, and it is necessary for the dispatcher to pick them up and transport them to the machine on which the first manufacturing operation is planned.

This activity requires 30 minutes for realization, and a necessary resource for transport is the forklift.

- *Activity 2: Turning;*

In the turning operation, the cutting tool is set at a certain depth of cut, and it travels to the left with a defined velocity while the workpiece rotates. The distance that the cutting tool passes horizontally per unit revolution of the workpiece presents the feed. The linear motion of the cutting tool produces a chip, which moves up the face of the cutting tool during the operation. [7]

Operations related to turning include facing, boring, and drilling. Turning, boring, and drilling operations are implemented to create cylindrical or more complex surfaces of rotation. The facing operation is implemented to create a flat surface that is normal to the axis of rotation by linear motion on the tool from the surface towards the center or outward from the center. [16]

This turning operation (of the shorter side of the clutch hub) is performed on the computer numerically controlled (CNC) "Spinner" lathe. The required production time on this CNC lathe is reduced in comparison with performing the turning operation on universal lathes. When the mechanical engineer determines the cutting conditions, chooses the cutting tools and indexable inserts, and creates the program of instructions to control the CNC lathe, the turning operation begins.

The controller always controls the first workpiece (the following workpieces are controlled randomly) using control tools determined in the operating sheet. Each workpiece that meets the defined requirements is placed in a metal basket (with a green label). Workpieces that do not meet the requirements (and there is a possibility for correction) are placed in a basket marked with a yellow label or immediately returned for re-turning. All workpieces that do not have excess material and do not have any possibility of correcting the dimensions are considered scrap and are left in a metal basket marked with a red label. The basket with the correct workpieces remains next to the lathe because the turning required in the second activity is performed on the same lathe (and in the same department).

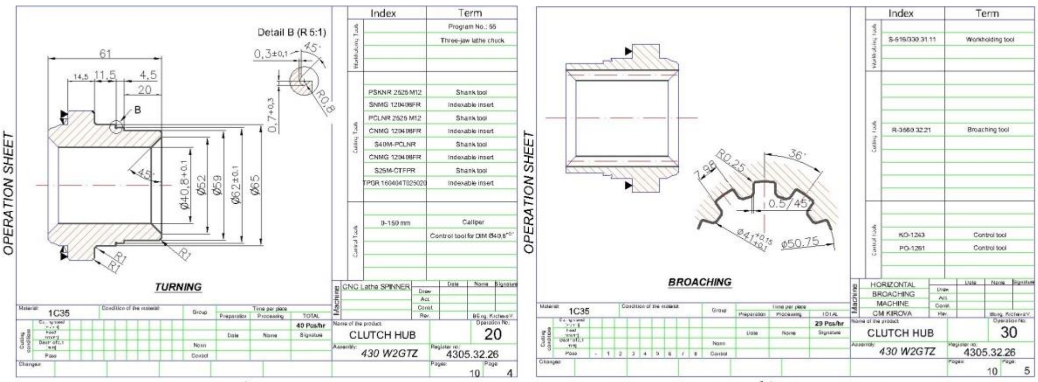
This activity requires 6.5 hours for realization, and the necessary resources are the CNC lathe on which the turning operation is performed, the operating sheet for the operation (Fig. 1c), and the workholding, cutting, and control tools.

- *Activity 3: Turning;*

This turning operation is performed on the same CNC "Spinner" lathe. Although the lathe is the same, there are differences in the implementation of the operation. It is impossible to use the same program of instructions to control the CNC lathe because the final contour is different. It refers to the longer side of the clutch hub, where the holding and basing are not applied to the forged surface but to the new, already machined surface from the previous operation. Considering the base is on a centric surface, all deformations and any non-centricity in terms of shape and dimensions are eliminated.

It is significant that the dimensional accuracy and quality of the surface finish achieved by CNC lathes cannot be achieved by conventional lathes. [13] In this manufacturing operation, the mechanical engineer defines all tasks that need to be undertaken, and the controller performs the control for the first workpiece as well as for the other workpieces selected at random. The machined workpieces are selected in baskets again.

This activity requires 2.5 hours for realization, and the necessary resources are the CNC lathe on which the turning operation is performed, the operating sheet for the operation (Fig. 2a), and the workholding, cutting, and control tools.



a) b)

Figure 2. *(a) Turning operation, (b) Broaching operation*

- *Activity 4: Transportation of workpieces from the CNC "Spinner" lathe to the conventional horizontal broaching machine "CM KIROVA";*

The CNC "Spinner" lathe and the conventional horizontal broaching machine "CM KIROVA" are located at a distance from each other in the Machining department. Therefore, the dispatcher, with a forklift, transports the metal basket (which contains the workpieces that meet the requirements in the operation sheet) from the CNC lathe to the horizontal broaching machine.

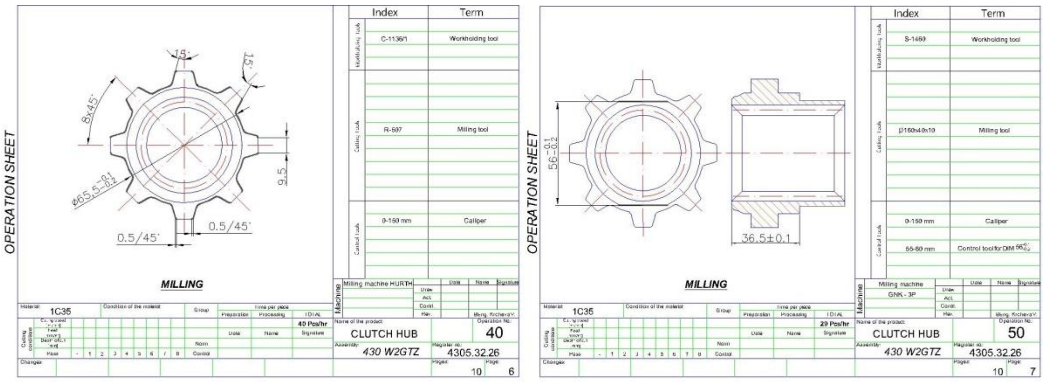
This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

- *Activity 5: Broaching;*

The broaching operation is performed on the broaching machine, which implements a rectilinear movement of the broaching tool (broaching mandrels) to machine the workpieces using the technology of metal chip processing. The workpiece is placed in a positional jig without clamping, where it is centered by the broaching tool during the process. Since broaching tools are expensive, this operation is suitable for series production. [11]

The broaching operation offers very high productivity and surface quality when the conditions are defined properly. One of the advantages over other machining operations is the fact that roughing and finishing a complex geometry of the workpiece can be completed in one pass in the operation, which can require many passes in another manufacturing operation (such as milling). [12]

This activity requires 3.5 hours for realization, and the necessary resources are the conventional horizontal broaching machine "CM KIROVA", where the broaching operation is performed, the operating sheet for the operation (Fig. 2b), and the workholding, cutting, and control tools.



a) b)

Figure 3. *(a) Milling operation, (b) Milling operation*

- *Activity 6: Transportation of workpieces from the conventional horizontal broaching machine "CM KIROVA" to the conventional milling machine "HURTH";*

Because of the physical distance between these two machines in the Machining department, the dispatcher transports the metal basket with the correct workpieces to the conventional milling machine "HURTH" with a forklift.

This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

- *Activity 7: Milling;*

In the milling operation, the rotating tool with multiple cutting edges moves slowly across the workpiece to generate a new plane of straight surface. The speed motion is provided by the rotating milling cutter, while the direction of the feed motion is perpendicular to the axis of rotation of the milling tool. This operation is performed on conventional milling machines, operated by a human operator who loads and unloads the workpieces, changes the cutting tools, and sets the cutting conditions. [5]

This activity requires 2.5 hours for realization, and the necessary resources are the conventional milling machine "HURTH", where the milling operation is performed, the operating sheet for the operation (Fig. 3a), and the workholding, cutting, and control tools.

- *Activity 8: Transportation of workpieces from the conventional milling machine "HURTH" to the conventional milling machine "GNK-3P";*

The dispatcher transports the basket of workpieces with a forklift to the "GNK-3P" milling machine because, despite the location of the machines in the same department, there is a physical distance between them.

This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

- *Activity 9: Milling;*

The milling operation is performed on milling machines, which are available in many different designs and capable of a wide range of applications. The milling machines remove the excess layer of material from the workpiece with a rotating multi-tooth cutter. This machine follows the lathe in the hierarchy of manufacturing machines because it provides a wide range of functions at a high rate. Considering that turning operations should ideally be performed on a lathe, milling operations, which include indexing the periphery of the workpiece, should ideally be performed on a milling machine. [8]

This activity requires 3.5 hours for realization, and the necessary resources are the conventional milling machine "GNK-3P", where the milling operation is performed, the operating sheet for the operation (Fig. 3b), and the workholding, cutting, and control tools.

- *Activity 10: Transportation of workpieces from the universal milling machine "GNK-3P" to the induction tempering machine;*

The induction tempering machine where the next manufacturing operation is performed is located in another department, the Heat treatment department. Therefore, the dispatcher transports the basket with the workpieces from one department to another, i.e., from the universal milling machine "GNK-3P" to the induction tempering machine.

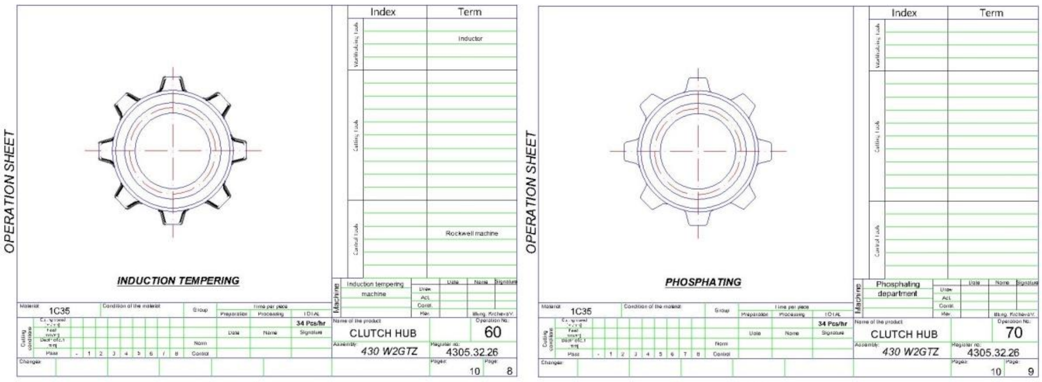
This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

- *Activity 11: Induction tempering;*

Tempering is a heating process implemented to reduce the brittleness and improve the toughness of the workpiece. The hardness of tempered martensite decreases with increasing tempering time and temperature. In tempering, the workpiece is heated to a specific temperature according to its composition and then cooled at a predetermined rate. [7]

Induction tempering refers to selective tempering, and this operation is applied to a certain area of the workpiece, i.e., the external surface of the workpiece. As a result, a layer of precisely hardened material forms on the surface of the workpiece to extend its life during operation in the vehicle. The value of the hardness is measured using a Rockwell machine.

This activity requires 3 hours for realization, and the necessary resources are the induction tempering machine on which this operation is performed, the operating sheet for the operation (Fig. 4a), and the Rockwell machine.



a) b)

Figure 4. *(a) Induction tempering operation, (b) Phosphating operation*

- *Activity 12: Transportation of workpieces from the induction tempering machine to the Phosphating department;*

The dispatcher, with a forklift, transports the workpieces from the Heat treatment department to the Phosphating department, where the next manufacturing operation is realized.

This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

- *Activity 13: Phosphating;*

Phosphating is the most common metal pretreatment method for the surface treatment and finishing of ferrous and non-ferrous metals. It performs an essential function in the automotive, process, and appliance industries because of its reasonable cost, speed of operation, and ability to afford excellent corrosion and wear resistance, adhesion, and lubricative properties. Although this method was initially developed as a simple method for preventing corrosion, the constant change and applications of phosphate workpieces contributed to the modification of the existing method and innovations to replace the conventional ones. [15]

This activity requires 3 hours for realization, and the necessary resources are the phosphating plant and the operating sheet for the operation (Fig. 4b).

- ❖ *Activity 14: Transportation of clutch hubs from the Phosphating department to the warehouse;*

Because the manufacturing process to produce the clutch hubs is complete, the dispatcher, with a forklift, transports the produced clutch hubs from the Phosphating department to the warehouse. After the clutch hubs are transported, they remain in the warehouse before being assembled into the final clutch disc.

This activity requires 30 minutes for realization, and the necessary resource for transport is the forklift.

3. Results and discussion

The manufacturing process explained above, defined as a certain project via Gantter, is visually presented in the Gantt chart (Fig. 5).

The activities (which appear as tasks) are listed on the left side of the Gantt chart, while an appropriate time scale follows along the right side. Each activity is represented by a bar. The position and length of the bar correspond to the duration, start date, and end date of the activity. This allows the beginning, duration, and end of each activity (which are explained above) to be clearly visualized. In that way, the start and end dates (according to the defined norms in the operations sheets) can be estimated. If it is assumed that the start date is December 5, 2023, and the end date is December 8, 2023, the manufacturing process will be completed in 4 days.

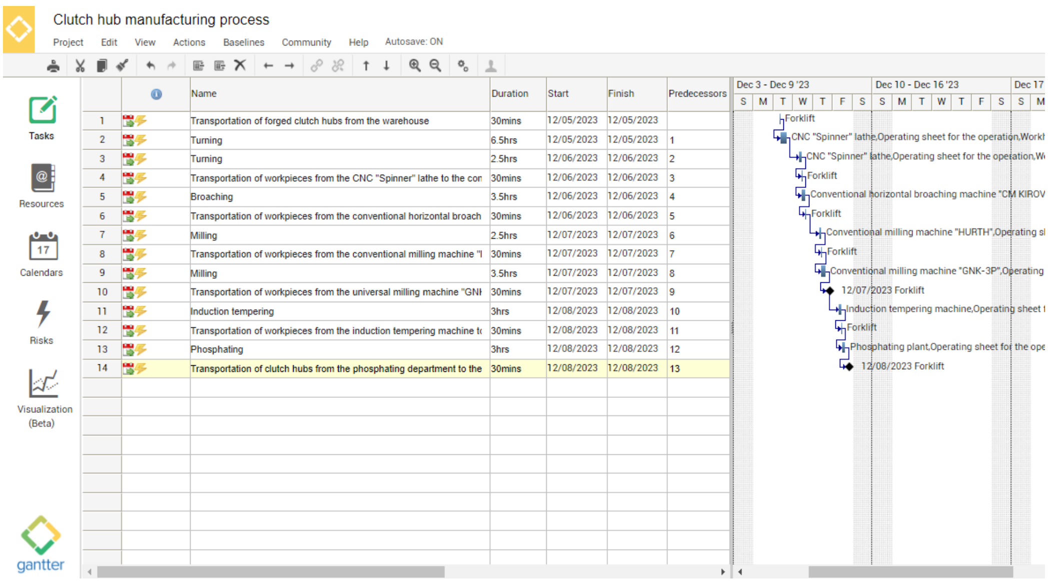
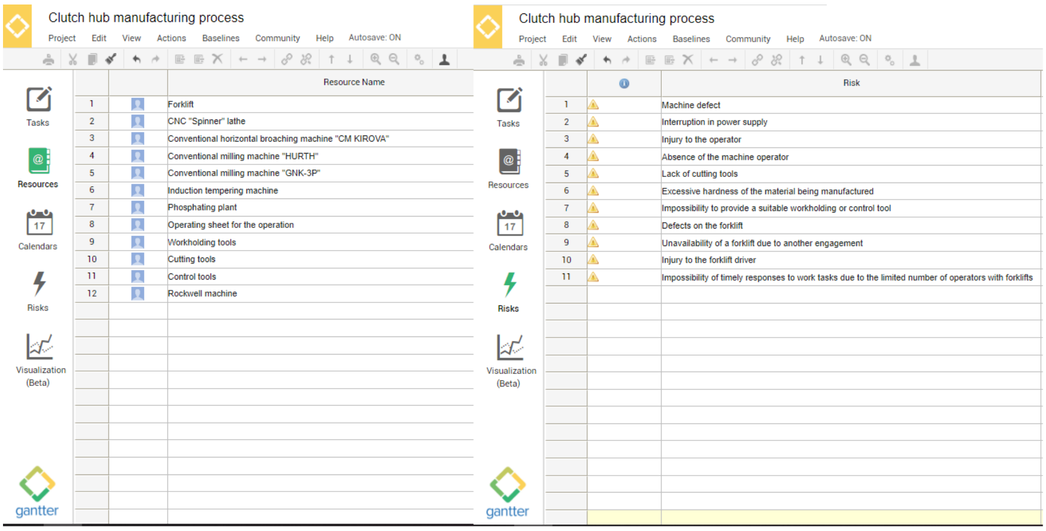


Figure 5. *Gantt chart*

Under the activities, on the left side, the resources are listed. They are the necessary assets whose main role is to help realize the activities and the whole project. Each activity requires different resources, which are explained above for all activities and illustrated in Figure 6a.

For each of the activities, there are some *risks* that can prolong or completely stop the realization of the activity. The icon Risks, which contains evidence of the possible risks, appears in the fourth row of the left side of the Gantt chart (Fig. 6b). Possible risks for the activities related to the manufacturing operations are machine defect, interruption in power supply, injury to the operator, absence of the machine operator (if only one operator is trained for a specific machine), lack of cutting tools (as reserve ones), excessive hardness of the material being manufactured, impossibility to provide a suitable workholding or control tool, etc. On the other hand, in activities related to forklift transport, risks that may occur are defects on the forklift, unavailability of a forklift due to another engagement, injury to the forklift driver, impossibility of timely responses to work tasks due to the limited number of operators with forklifts, etc.



a) b)

Figure 6. *(a) Resources, (b) Risks*

Task properties (as well as risks) are available for each activity and are placed on icons before the name of the activity in Figure 5. Except for risks, they include descriptions of general and advanced information, notes, links, dependencies between activities, etc. Considering the risks and task properties before starting the manufacturing process contributes to preventively eliminating the possible risks and problems in the activities.

Relations between activities are used to visualize how the activities are connected and how they depend on one another. The dependencies of the activities are shown as lines between the activities in the bar section on the Gantt chart. It is obvious that each activity depends on the previous one. That means the realization of each activity enables the realization of every subsequent activity. On the other hand, when the realization of every previous activity prolongs, the realization of every next activity also prolongs. The dependence of the activities is shown in the Predecessor column in Figure 5.

To control the realization of the activities and monitor the progress of the project, there are two defined milestones. These milestones are shown as a grey diamond image in the Gantt chart and are centered on the provided start time in Figure 5.

The first milestone is the 10th activity ”Transportation of workpieces from the universal milling machine "GNK-3P" to the induction tempering machine”. This event is important because the workpieces are transported from one department to another. The activities up to this moment have been realized in the Machining department. The completion of then manufacturing operations with the removal of material and then the affirmation from the controllers are the key factors before transporting the workpieces to the Heat treatment department. When it is confirmed that the workpieces meet the qualitative and quantitative requirements of the process, the responsibility of the employed operators, controllers, and engineers in the Machining department ends. All additional risks and errors that may appear during the next manufacturing operations are the responsibility of employees in the other departments, respectively.

The second milestone is the 14th activity “Transportation of clutch hubs from the Phosphating department to the warehouse”. The workpieces have already become finished products. The manufacturing process for their production has finished. Then the clutch hubs are transported to the warehouse until they are assembled into the final clutch discs.

4. Conclusion

Considering the simplicity and flexibility of the Gantt chart, it is widely used by many project managers to prepare project plans and schedules. The primary objectives of the Gantt chart are to estimate how long a project should take and to determine the sequence in which activities should occur before the project is complete.

Some advantages of the Gantt chart are that it is easy to create and easy to read. It enables a clear understanding of the project through a plain visualization of the information about the various activities that are included in the project, when they begin and end, how long they are scheduled to last, the start and end days of the whole project, where one activity overlaps with another (and by how much), which the milestones are, the resources, the risk, etc.

This study is further recommended for planning in the manufacturing industry when the real manufacturing processes are analyzed and discussed as specific projects defined by appropriate activities and estimated by project management tools when attempting to create a project plan for a real manufacturing process.

References

[1] *Burghate, S* (2017). Preparing Gantt Chart for a Project, International Journal of Commerce and Management Studies (IJCAMS), Vol. 2, No. 4

[2] *Darnall, R., W and Preston, J., M* (2012). Beginning Project Management, 5th ed.

[3] *Evdokimov, I., V and Tsarev, R., Y and Yamskikh, T., N and Pupkov, A., N* (2018). Using PERT and Gantt charts for planning software projects on the basis of distributed digital ecosystems, Journal of Physics: Conference Series, Vol. 1074, Doi 10.1088/1742-6596/1074/1/012127

[4] *Geraldi, J and Lechler, T* (2012). Gantt charts revisited: A critical analysis of its roots and implications to the management of projects today, International Journal of Managing Projects in Business, Vol. 5, No. 4, DOI 10.1108/17538371211268889, pp. 578-594

[5] *Groover M., P* (2010). Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 4th ed., John Wiley & Sons, Hoboken, USA

[6] *Heagney, J* (2012). Fundamentals of Project Management, 4th ed., American Management Association, New York, USA

[7] *Kalpakjian, S and Schmid, S., R* (2009). Manufacturing Engineering and Technology, 6th ed., Prentice Hall, Singapore

[8] *Kaushish, J., P* (2010). Manufacturing Processes, 2nd ed., PHI Learning, New Delhi, India

[9] *Larson, E., W and Gray, C., F* (2011). Project Management: The Managerial Process, 5th ed., McGraw-Hill/Irwin, New York, USA

[10] *Lester, A* (2017). Project Management, Planning and Control, 7th ed., Butterworth-Heinemann, Oxford, United Kingdom

[11] *Martinovic, J and Peterka, J* (2021). Technology of broaching – Research of the roughness and machine capability, MM Science Journal, Vol. 6, DOI 10.17973/MMSJ.2021_12_2021187, pp. 5452-5459

[12] *Özelkan, E., C and Öztürk, Ö and Budak, E* (2007). Optimization of Broaching Design, Industrial Engineering Research Conference

[13] *Pant, G and Kaushik, S and Rao, D., K and Negi, K and Pal, A and Pandey, D., C* (2017). Study and Analysis of Material Removal Rate on Lathe Operation with Varying Parameters from CNC Lathe Machine, International Journal of Emerging Technologies, Vol. 8, No. 1, ISSN 2249-3255, pp. 683-689

[14] *Ramachandran, K., K and Karthick, K., K* (2019). Gantt Chart: An Important Tool of Management, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol. 8, No. 7C, ISSN 2278-3075, pp. 140-142

[15] *Takle, V and Karwande, R and Dhole, S and Irfan, M* (2021). Review on Systematic Approach to Phosphating and Passivation for Improvement in Surface Properties, IJARIIE, Vol. 7, No. 6, ISSN 2395-4396, pp. 1216-1221

[16] *Trent, E., M and Wright, P., K* (2000). Metal Cutting, 4th ed., Butterworth-Heinemann, Oxford, United Kingdom

[17] *Watt, A* (2014). Project Management, 2nd ed., BCcampus Open Education, Canada

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