

An Approach Development of Process Planning of a Bevel Gear

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Abstract— An approach for developing process planning of a bevel gear is proposed way to perform and describe the procedure of creating a process plan. The method facilitates the interpretation and understanding of the plan, not only immediately for the process planner responsible, but also for designers, engineers, researchers and other interest groups involved in a manufacturing process. This research has been performed in an industrial environment by CNC machining for manufacturing of a bevel gear. The methods and results presented are generally applicable to developing the method of process planning of a bevel gear. This work is a monograph and the aim has been to provide a thorough overview of process planning as whole and to present the great complexity therein. The presented results in this work are based on process planning sheet, schematic process planning sheet and machining operations planning summary study in industry.

Key words: Process Planning, CNC Machining, CAPP, Process Performance, Process Capability

I. INTRODUCTION

In every situation when a new product is to be manufactured, there must be several decisions made by someone with process planning skills about how this shall be managed. Process planning is important work because it significantly influences the cost of components and it affects company competitiveness, production efficiency and quality of the product (Helevi and Weill, 1995)^[1]. Process planning can then be regarded as all the activities necessary for giving instructions on how to bring a virtual product into the physical world.

Process planning is defined as the systematic determination of the detailed methods by which work pieces or parts can be manufactured from initial stages (raw material form) to finished stages (desired form). The complete process planning is indicating in figure1. Process planning is a result of engineering planning activities of process planners which prepare a list of processes needed to convert a raw material shape as a starting point into a predetermined final shape. A process planner has to consider the mentioned parameter and to propose an optimal process plan. The optimal process plan has to fulfill the selected production criteria (cost, time, quality).



Fig. 1: Bevel Gear with pinion.

Gear production is an area where the process planning is an important activity due to the close

relationships between gear design and manufacturing methods. Gear geometries are associated with complicated generating kinematics (Britton et al., 2002)^[2]. Machining and measuring possibilities define what the gear designer has to deal with. The complete gear part (gearwheel, shaft etc.) is produced using both machines and tools that are specially developed for gear manufacturing, and with standard machine tools for common methods like turning, hardening and grinding (Bagge, M)^[3].

II. LITERATURE REVIEW

Many researchers of technical literature describe and try to develop process planning from different viewpoints. There is a wide range of approaches, all with the intention of making process planning easier and more time efficient.

Bagge, M. (2014)^[4] presented a method all-embracing aim of finding methods that cover essential activities for process planning, including abilities to predict the outcome of a proposed manufacturing process. This is realized by gathering supporting methods suitable to manage both qualitative and quantitative characterization and analyses of a manufacturing process. The production research community has requested systematization and deeper understanding of industrial process planning. This work contributes with a flow chart describing the process planning process (PPP), in consequence of the methodological studies.

Gupta, S. (2014)^[5] presented a paper, Design and Process Planning of Micro Gear Manufacturing. The research activities are directed towards the downscaling of manufacturing procedures or the formation of complex process chains for the manufacturing of the micro work pieces in this paper he is going to design a micro gears and a suitable manufacturing process for making of micro gears.

Riyadh M. Ali Hamza, (2013)^[6] presented a study imitating a procedure of a Two Stages Gear Box (2SGB) assembly line layout is presented. Three balancing methods are studied in which 2SGB is assembled. These methods are Rank position weight, larger candidate rate, and Column method. The selection criterion was based on minimum assembly time for all method. Three assembly line processing layouts were developed based on output of assembly methods which are the single straight line, circle and mixed (circle + straight) processing.

Anderberg S. (2012)^[7] presented a methods for improving performance of process planning for CNC machining. This work has contributed to an enhanced understanding of how process planning improvements can be achieved through a holistic perspective of the process planning function, where both technical and methodological aids are included. It is however essential to understand the current situation of the process planning organization, its internal/external relations, level of digitalization, competency level etc. before major changes of the process planning function are undertaken in order to be successful.

Bagge, M. (2009) [3] studies an approach for systematic process planning of gear transmission parts. A method for systematic process planning is proposed as a way to perform and describe the procedure of creating a process plan. The method facilitates the interpretation and understanding of the plan, not only immediately for the process planner responsible, but also for designers, engineers, researchers and other interest groups involved in a manufacturing process.

III. METHODOLOGY

An approach for development of Process Planning of a bevel gear to support the possibilities to structure, identify, examine and evaluate details step by step but with a good overview. It will also facilitate easier process planning when single or extensive changes are introduced on a product or in a manufacturing process. In addition to the possibilities to establish documentation of the technical reasoning this will provide a way to describe the process planning work.

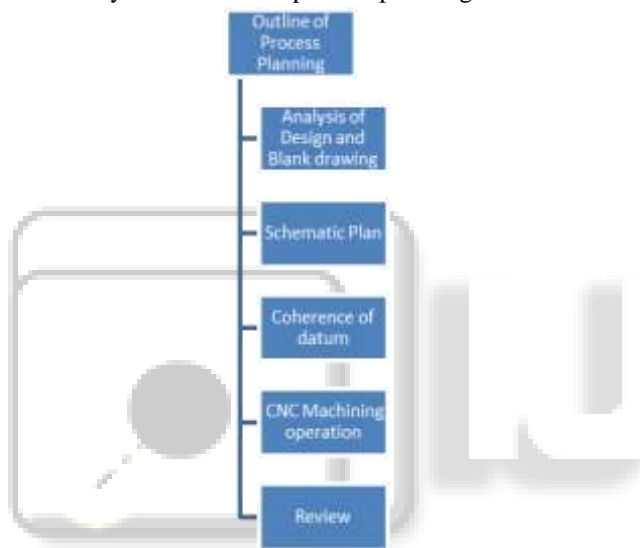


Fig. 2: Method Adopted for Developing Process Planning. The following items are identified as benefits that can be achieved when using the process planning sheets for process planning described in this research:

- Provides a way to describe schematic process Planning.
- Gives an overview of a complete process Planning.
- Facilitates easier analysis of each operation.
- Provides basic data for decision-making.
- Supports knowledge transfer.
- Facilitates manufacturing (process).
- Develops process planning progress.
- CNC machining operations (process planning Summary).

IV. OBSERVATION

The manufacturing process for gear is divided into three sub-processes;

- Soft machining,
- Heat treatment and
- Hard machining.

These three sub-processes contain various multi-step machining or heat treatment operations organized on different kinds of manufacturing lines.

S. No.	Raw Material	Soft-Machining	Heat-Treatment	Hard-Machining
1	AISI4142 alloy steel	Turning	Carburizing	Tuming/ Grinding
2	AISI4142 alloy steel	Drilling	Quenching	Honing
3	AISI4142 alloy steel	Gear Cutting	Tempering	Gear cutting

Table 1: Manufacturing process chain of Gears.

Process Planning Sheet					
Item name : Bevel gear			Materials: AISI4142		
Format No: G/Prod/RC			Customer order No: XYZ		
Date: 04/05/2015			Model No: G0125		
Order quality: 29			Checked: C.S. Good		
S. N.	Operation No.	Operation description	Machine	Set-up time (min)	O/p time (min)
1	10	Metal cutting	Hor. Hacksaw.	10	30
2	20	Rough turning	CNC lathe	10	60
3	30	Fine turning	CNC lathe	30	110
4	40	Gear cutting	CNC hob.	50	170
5	50	Face milling	VMC	30	60
6	60	Centre hole drilling	CNC vert. m/c	25	50
7	70	Lapping of gear	CNC vert. m/c	20	52
8	80	Surface grinding	Grinder	15	45
9	90	Spline hobing	CNC hobing m/c	50	70
10	100	Heat treatment		25	57
11	110	Quality inspection	Quality dept.	20	20
12	120	FG Transfer	M.H. devise	0	20

Table 2: Complete process planning sheet

This table is emphasized by the company strategy, advocating both systematic planning operations and manufacturing process design, which in turn characterizes the process planning work.

Materials used for bevel gear manufacturing in this research AISI4142 alloy steel (UNS G4142). The compositions of bevel gear materials are:

Cr(0.80-1.10)%; Mn(0.75-1.10)%; C(0.40-0.45)%; S(0.04)%; Si(0.15-0.40)% and balance Fe(96.72)%.

A. Analysis of the Design and Blank Drawing

The bevel gear pinion exemplified in this case belongs to a family of central gears with different gear ratios. The difference is the number of teeth and the design of the gear to achieve these ratios with required characteristics. This idea makes it possible to use the same design for the “shaft” for all pinions in the family. The pinion “head” is suited to

fit a certain gear design. In the beginning of a process planning job, the analysis and interpretation of design data is essential. To review design data from a manufacturing point of view, the model or drawing should be considered in the following order:

- Application of the part.
- Design datums.
- Requirements related to datums.
- Associated dimensions and features..
- Influence of blank.

- The ability to measure and verify quality.

B. The Schematic Plan

It is necessary to get a good overview of the complete process chain. Therefore, the schematic plan is introduced as a platform for the continuing process planning work. The primarily contribution to better process plans is that the operation sequence, relationships between operations, detailed facts, intentions, decisions etc. can be continuously visualized and documented in an uncomplicated way.

Schematic Process Planning Sheet					
Part No: G0125		Material: AISI4142 A.S.		Part Name: Bevel gear	
Original: S.D smart		Date:09/5/2015		Checked: C.S. Good Approved: RPML	
O/p No.	O/p description	Work-station	Set-up	Tool	Time (Min)
10	Raw material cutting	Hac. m/c 01	Set on left corner	Super finishing teeth hac. blade	3 Setup 10 cutting
20	Taper turning	CNC m/c 02	Set on surface 01	Turning tool 2" dia.	5 setup 20 machining
30	Face milling	VMC 03	Set on surface 02	Milling cutter 52 teeth	7 setup 20 milling
40	Center hole drilling	DRL 03	Set on surface 03	Twist drill 1/2" dia.	3 Setup 9 drilling
50	Surface grinding	GRI 04	Set on right corner	Smooth grinder	2 Setup 8 grinding
60	Gear cutting	Hob 04	Set on surface 04	hobing tool	10 setup 25 machining

Table 3: Schematic process planning sheet

Schematic process planning includes, for example, definition of production and operation sequence, machine tools, cutting and work holding tools. Table 4 indicates schematic process planning sheet to manufacture a gear in industry.

C. CNC Machining Operations (Operation Planning Summary)

In this step consequences of the present plan will be evaluated in order to find out how well the process will work. The overall target is to get a process that behaves as expected. If this is achieved, tolerance requirements can be related to the outcome produced and a process capability can be estimated. If the capability is considered as being good enough, the process planning work can continue. Table 4 shows the process parameter in a CNC machining.

Cutter Related	Machine Related	Work piece Related
1. Material 2. Geometry 3. Mountings	1. Cutting fluid 2. Depth and width of cut 3. Spindle speed 4. Feed rate	1. Material 2. Geometry 3. Depth of cut 4. Spindle speed 5. Feed rate

Table 4: Process parameters in a CNC m/c

S. No.	Operations Description	Part	Tool	Material	Quantity	O/p Status
1	Rough cutting	Bevel Gear	Cutting tool	AISI4142	1	
2	Fine turning	Bevel	Turning tool	AISI4142	1	

		Gear				
3	Center hole drilling	Bevel Gear	Drilling tool	AISI4142	1	
4	Bevel gear cutting	Bevel Gear	Hob. Tool	AISI4142	1	
5	Spline hobbing	Bevel Gear	Hobbing tool	AISI4142	1	
6	Surface grinding	Bevel Gear	Surface Grinder	AISI4142	1	
7	Face milling	Bevel Gear	Milling cutter	AISI4142	1	
8	Lapping of gear	Bevel Gear	Hob. Tool	AISI4142	1	

Table 5: Operations status of machining

Note: To Be Done X Complete

D. Reviews

Things that were difficult to foresee at the start, or that needed to be confirmed in the context of a better defined process, may now result in a need to change for example manufacturing sequence, type of fixture, control strategy or

maximum cutting forces. This implies that new choices and decisions must be taken for develop a process plan for improve performance and efficiency.

V. CONCLUSION

Process planning has gained deeper insight into the topic and some results is draw as follows:

- 1) Making a process plan, facilitates highlights of the most sensitive operations due to quality but also other factors that influence process efficiency.
- 2) The use of process planning sheets solves problems practically if there are sufficient data and constraints. In practice is it not possible to collect valid data for all parameters that theoretically can affect the process.
- 3) The nature of process planning as a multifactor process is managed in a simpler way by using a systematic, standardized method. This will support making process plans where the result will be more effective and high understandable.
- 4) If the knowledge, thinking and logics before a plan is described there is a good possibility of reaching higher levels of understanding. The plan is used as a master plan where intended deviations need a mandatory decision with full awareness of the consequences.
- 5) This approach development of process planning of a bevel gear is facilitate more efficient process planning.

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