

HOW TO INCREASE THE VALUE OF MANUFACTURED PARTS

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ABSTRACT

It will be shown that Value Analysis (VA) is a way to avoid rejects at the manufacture, increasing the value for the producer and also improve performance, thus increasing the value for the user.

UNDESIRABLE EFFECTS TO BE ELIMINATED

It may be frequent for a company, to have manufacturing difficulties and rejects due to impossibilities to accomplish demanded accuracy indicated in the drawings, resulting in rejects of sub-assemblies or even finished products. It is even more disappointing, to discover that those parts could have been approved, even though manufactured by the same equipment.

Another problem, not so frequent, is the rejection of the assembled products, having the components manufactured meeting the drawing requisites.

It is very lasting and not elegant to establish manufacture sequence using the trial and error method, because it will originate waste.

A less visible but much more frequent problem, is to miss the due dates, bringing in many cases, the apparent need of acquiring more equipments.

Considering the necessity to be competitive, the improvement of the working conditions of our products is important. It can happen that such improvement is not considered when it could be offered without any additional difficulty.

These six undesirable effects are analyzed having in mind determining their causes, and proposing solutions.

INTRODUCTION

Generally products are manufactured based on drawings which guide and orient people from the raw material until the

finished product.

The drawings are characterized by having dimensions with tolerances to be met during the manufacturing process.

From the user's point of view, some dimensions are more important than others, and are associated with tighter tolerances, therefore more difficult to be obtained.

Functional Dimensions (FD) are those influencing directly on the user's expected characteristics of the products. These characteristics are called working conditions (WKC).

Each FD is obtained through equipments, which, due to statistical fluctuations, should be provided with tolerances so that they can correspond to the actual manufactured parts.

The working conditions (WKC) result from various FD, therefore resulting in an accumulation of tolerances.

The focusing process developed by Goldratt in Theory of Constraints suggests to consider a system, define its goal and then identify the constraints, decide how to exploit them, subordinate everything else to the above decision, elevate the systems constraints, and, if in the previous steps a constraint has been broken, go back to step one.¹

Value Analysis (VA) is an organized effort directed to analyze functions of goods and services to accomplish those necessary functions and essential characteristics in a more profitable way.²

SEARCH OF CAUSES OF THE UNDESIRABLE EFFECTS

A powerful way of investigating the relationship of causes and effects is the Effect-Cause-Effect Tree, used for scientific research. Starting from the undesirable effects, causes are postulated and validated. This process is continually repeated until the most profound causes are reached, identifying then the core-problems, as can be seen in fig. 1. This is a very useful tool to identify the functions to be approached.³

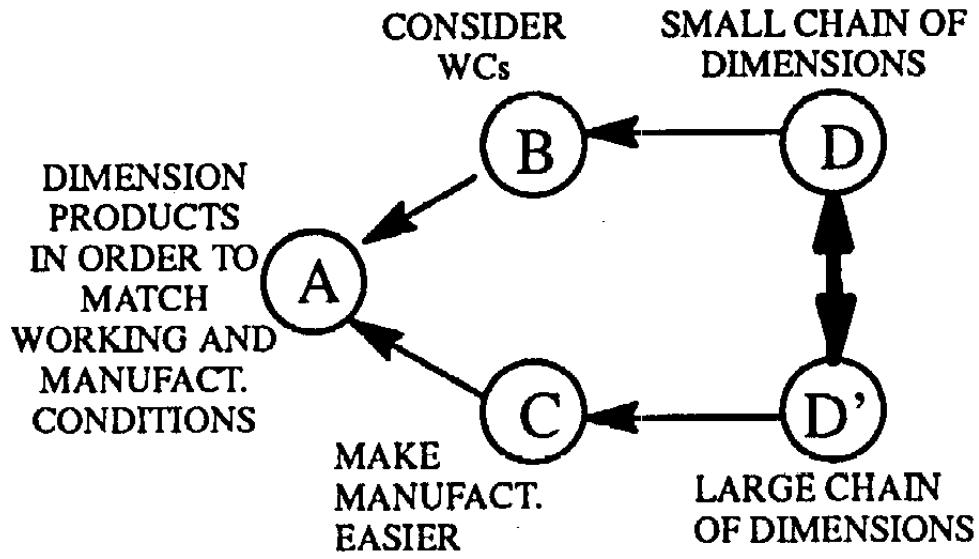


Fig.2-Formulate the Product Dimensioning Problem

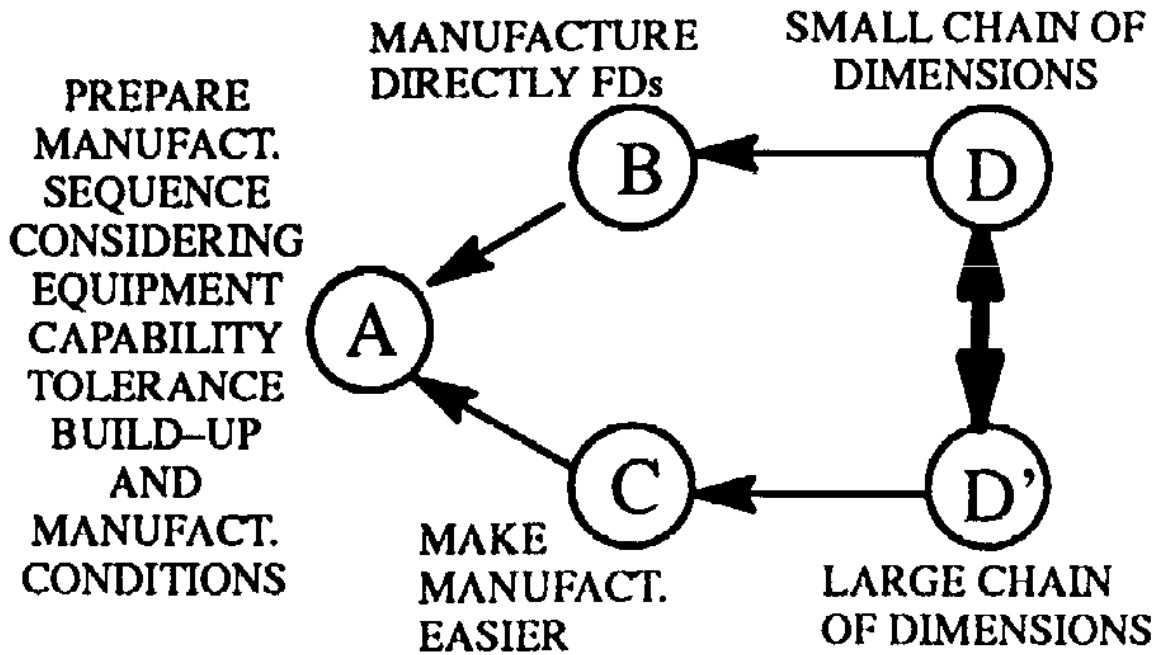
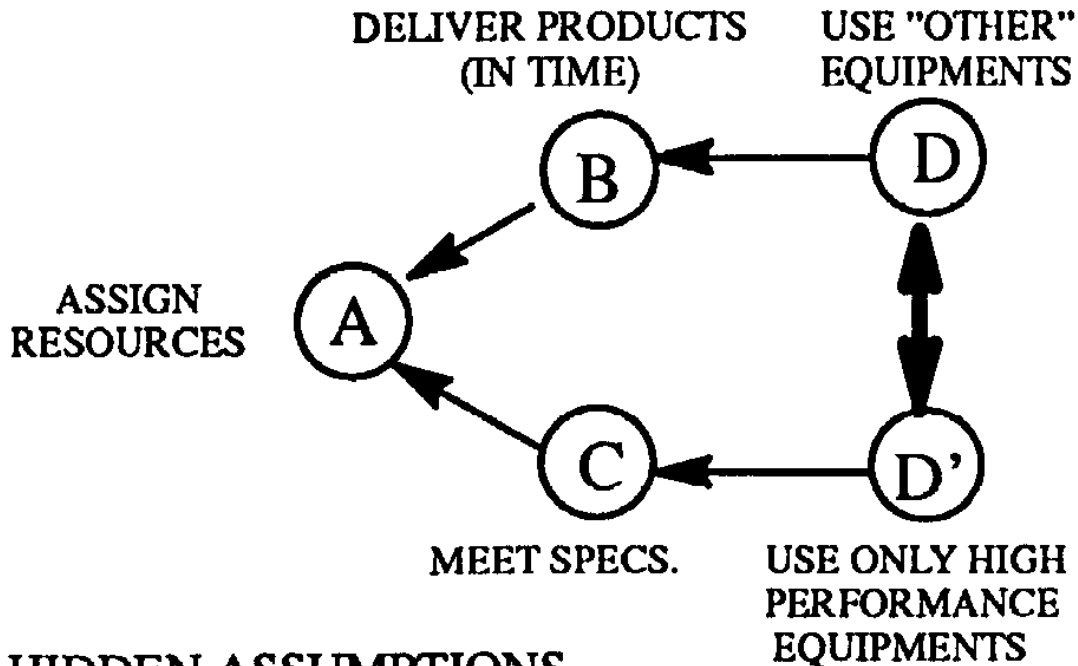


Fig.3 – Formulate the Manufact. Sequence Preparation Problem



- AB: PRODUCTS ARE MANUFACT. "AT HOME"**
- AC: CONSIDER EQUIPMENTS CAPABILITY**
- BD: CONSIDER ALTERNATIVE POSSIBILITIES**
- CD': NO TRANSFER WORK FROM ONE EQUIP. TO OTHERS**
- DD': TO ASSIGN RESOURCES NEED TO USE EQUIPMENTS**

Fig.4—Formulate the Resources Assignment Problem

Therefore in fig. 4 it can be considered that to perform the function Assign Resources it should be performed the functions Deliver Products and Meet Specifications. To Deliver Products (in time) it should be performed the function Use "Other" Equipments, and to Meet Specifications it should be performed the function Use Only "Accurate" Equipments.

It can also be concluded that the function Use "Other" Equipments is performed to Deliver Products (in time), as is the performance of the function Use Only "Accurate" Equipments to Meet Specifications.

At last, it can also be considered that it should be performed both functions Deliver Products (in time) and Meet Specifications to Assign Resources. It is a method that differs from the well-known FAST (Function Analysis System Technique) which can be applied also in Quality subjects.⁵

There is a hidden assumption behind each arrow, that must be surfaced. The invalidation of any of these hidden assumptions will make the conflict disappear.

The following hidden assumptions can be chosen to be invalidated:

- there is no relation between WKC's and FDs (CD' - fig.2);
- there is no relation between FDs and manufacturing dimensions (CD' - fig.3);
- there is no transferring of work from one equipment to another (CD' - fig.4).

The next step is to challenge these three conclusions.

THE CONSIDERED SYSTEM

If it is considered the goal of reinforcing the mechanical strength of a chain, two paths can be considered, which are, reinforce each link individually or discover which one is the weakest and reinforce it. The consumed resources for each case are substantially different. The difference between the two approaches is that through the first path, each link has been considered as a system, while through the other path, the whole chain has been considered as a system.⁶ Therefore it is useless to reinforce any link other than the weakest, because there would be waste of resources .

A company, like a chain, also has a goal which is to make more money now as well as in the future. Each part of the system of the company constitutes a sub-system, just like the links of the chain, interdependent in obtaining the final goal. That is, any part of the system can help or damage its final result in case it doesn't work correctly and synchronizedly.

Each product to be manufactured and sold must perform a set of the functions desired by the user or buyer. These functions

can be translated to drawing dimensions that result in clearances or interferences, which are the WKC's.

Each WKC depends on a set of components, and can be considered as a sub-system.

Therefore, if the simplified set of parts A and B in fig. 5 is assembled, the following WKC's can be imposed:

$$4.0 \text{ mm} > \text{WKC's} > 3.7 \text{ mm}$$

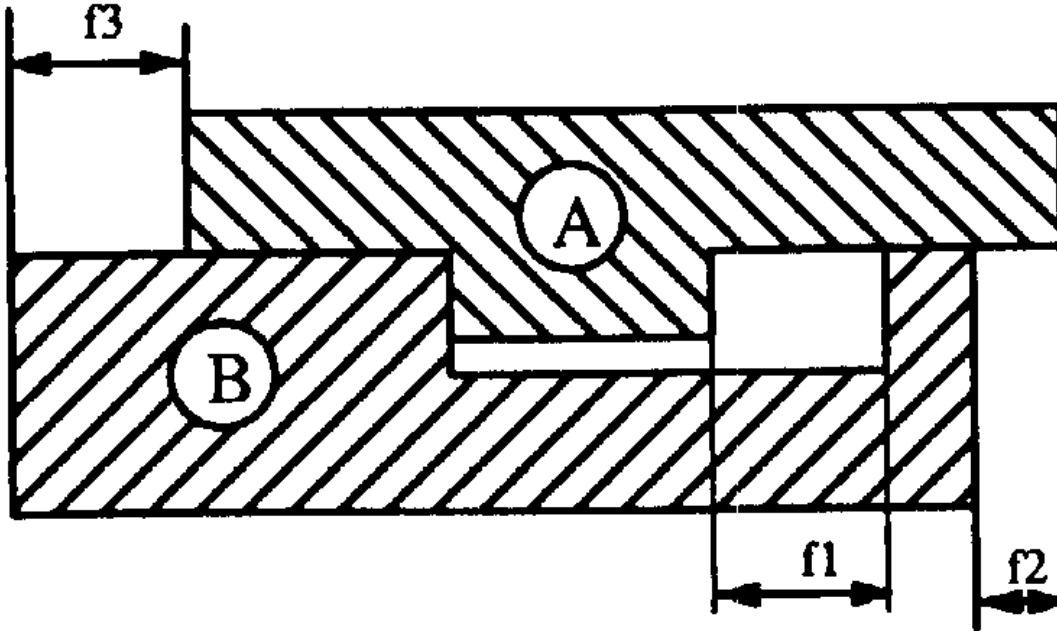


Fig.5 – AB Set Studied

f1- assures that there is a possibility of movement between A and B;

f2- assures that A always exceeds B (right side);

f3- assures that A always stays inside B (left side).

The goal of the system will be achieved with the execution of the WKC's measured in length, because this way the

consumer's satisfaction is guaranteed, thus contributing to the generation of more money by the company.

It is therefore important to recognize those parts and respective dimensions that comprise each sub-system, or WKC.

Each one of the parts is dimensioned by the Product Engineering Department, as shown in fig.6.

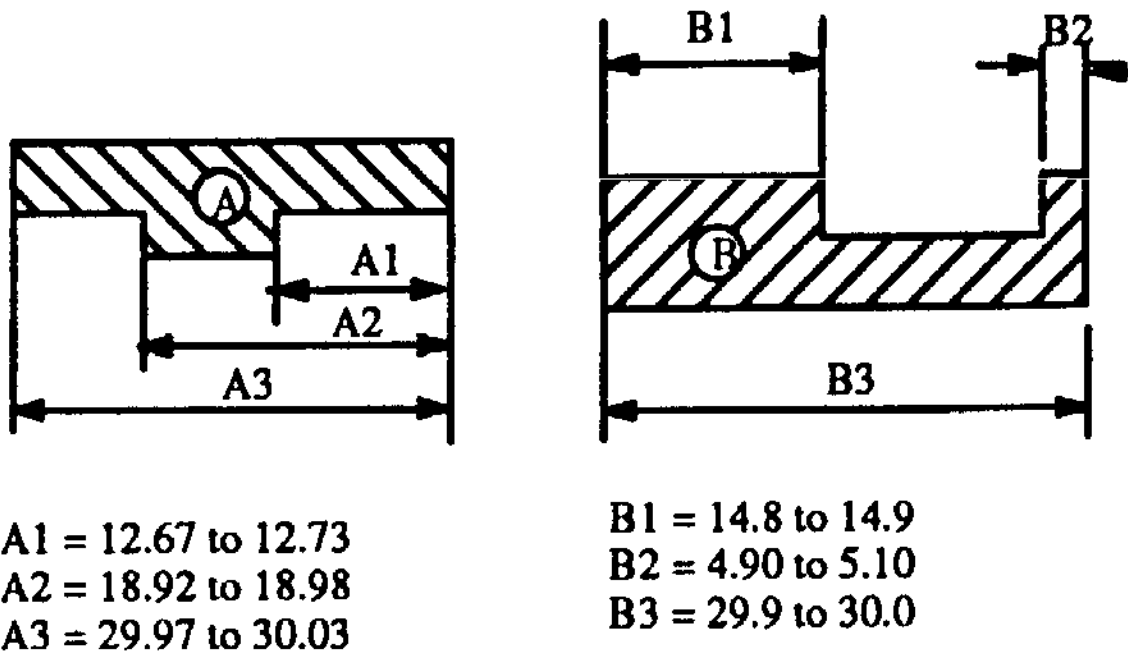


Fig. 6 – Dimensioning of Parts A and B

As the WKC's result of a set of asked dimensions, which result from other given or manufactured ones, it can be written, from the example in fig.5 and the indicated dimensions of A and B in fig.6, that:

$$f1 = (B3 - B1 - B2) - (A2 - A1)$$

$$f2 = A2 - (B3 - B1)$$

$$f3 = B1 - (A3 - A2)$$

Calling constraint anything that limits a system from achieving higher performance versus its goal, comes the necessity of identifying which are the constraints in this case.⁷

IDENTIFYING THE SYSTEM'S CONSTRAINTS

From the equations referring to the sub-systems, it can be verified that each of the dimensions must be obtained from adequate manufacturing equipment.

All manufacturing equipment keep a process capability, which can be measured through the manufactured dimension, that is, that one which depends exclusively from the considered process.

Considering the WKC's equations, the conclusion is: the greater the number of operations intervening in the system, the smaller is the tolerance range to be assigned to each dimension. This is because the WKC is a resultant from these operations on one hand and is determined by the Product Engineering Department on the other hand.

Thus, identifying the constraints corresponds to discovering which are the WKC's that might not be obtained, because of the tolerances needed from the equipments, and also corresponds to

pinpointing which are the equipments causing this.

Assuming that the equipments that execute part B, can not guarantee smaller tolerances than 0.2mm, and even in this case with difficulty, than this set of operations is considered a constraint that blocks the finalization of the dimensions chain. As a consequence, the realization of the goal of the company is also blocked. From this, it is necessary to search for ways to execute the above operations with 0.2mm of tolerance without jeopardizing the WKC's.

To use in the best way the equipments accomplishing B1, B2 and B3 is called exploiting the constraints.

HOW TO EXPLOIT THE CONSTRAINTS

If the sub-system f1 results from five interlinked elements, from which B1, B2 and B3 are difficult to obtain, comes the question "how to get the most accuracy from the system"?

As each component presents a variation and as they are interlinked in such a way that each must keep its accuracy to get the system to attain its goal, comes the conclusion: the less the amount of components, the bigger is the tolerance to be assigned for each without damaging the working conditions.

As a consequence, the only way to get a bigger tolerance per part, is to imagine an assembly kinematic chain which must be the shortest possible. This can be obtained considering only the dimensions linking the contact surfaces between parts and the surfaces determining the WKC's. Using the example of fig 5, the new dimension chains, or sub-systems change to:

$$f1 = B1' - A1'$$

$$f2 = A2' - B2'$$

$$f3 = B3' - A3'$$

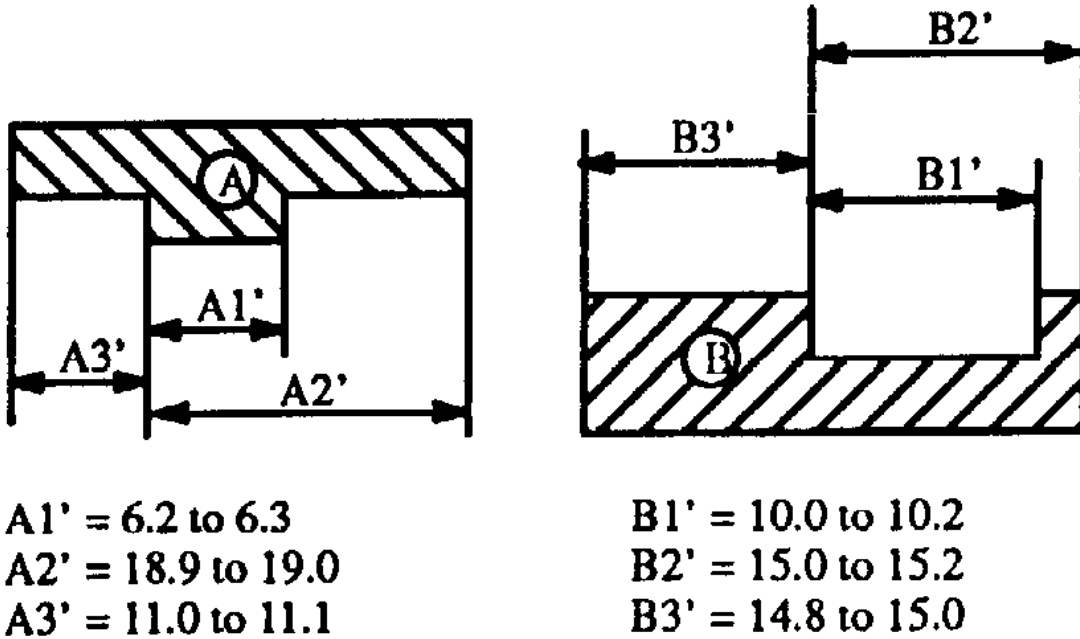


Fig.7 – Functional Dimensioning of A and B

bringing the possibility to increase the tolerances of the new dimensions, and making the best use of the problematic equipments. Such dimensioning is shown in fig 7, from which can be defined which are the tolerances to be assigned to those dimensions corresponding to the operations that are constraints.

A possibility to approach the problem, is to assign such a tolerance permitting the execution of these dimensions according to the capability of the involved processes and meeting simultaneously the WKC's.

Once the constraints are identified and a decision made of the best way to exploit them, everything else must be subordinated to this decision.

HOW TO SUBORDINATE THE OTHER RESOURCES

To subordinate the other operations to the identified constraints, means to utilize them in such a way as to help the attainment of the constraint operations.

In this case tighter tolerances should be required from the operations whose equipments permit it. Since all the dimensions are interlinked, there will be a compensation of the less accurate equipment executing B by the more accurate equipment executing A.

Therefore, for the first WKC:

dimension notation	nominal	tolerance
A1'	?	- 0.1
B1'	10.0	+ 0.2

f1 is maximum when:

$$f1M = B1'M - A1'm$$

$$4.0 = 10.2 - A1'm$$

$$A1'm = 6.2$$

f2 is minimum when:

$$f1m = B1'm - A1'M$$

$$3.7 = 10.0 - A1'M$$

$$A1'M = 6.3$$

So $A1' = \underline{6.2 \text{ to } 6.3}$

In the same way for the second WKC,

$$\underline{A2' = 18.9 \text{ to } 19.0}$$

And finally for the third WKC,

$$\underline{A3' = 11.0 \text{ to } 11.1}$$

If the tolerances of the obtained functional dimensions A1', A2' or A3' are less than the capability of the involved processes, there is a constraint to be "elevated" or eliminated. If the opposite is true, it can be considered the possibility of reducing the tolerance of the WKC, bringing more value to the user.

OBTAINED RESULTS

The six original dimensions A1, A2 and A3 of part A, and B1, B2 and B3 of part B, had tight tolerances and hardly obtainable with the available equipments, causing rejects. In spite of this, the WKC's weren't met, bringing assembly problems, especially in condition f1.

Now the proposed dimensions have bigger tolerances which can be obtained from the existing equipments, meeting thus the WKC's.

ELEVATION OF THE CONSTRAINTS

To elevate or eliminate the constraints means to act on them or on any parameter in such a way as to make the effect of these constraints disappear. This can be obtained by acting on the actual equipments or on the WWKCs without prejudicing the user's satisfaction.

Once the constraint no longer acts, it becomes necessary to identify the next one to keep a continuous track of value improvement.

PREP. OF THE MANUFACTURING PROCESS
ANOTHER SUB-SYSTEM

Another sub-system to be considered is the preparation of the manufacturing process starting from the product drawings and the data of the existing equipments.

Considering the manufacturing sequence of fig.8, the resulting tolerances (fig.9) show that dimension II has 0.24 mm as tolerance instead of 0.04 mm.

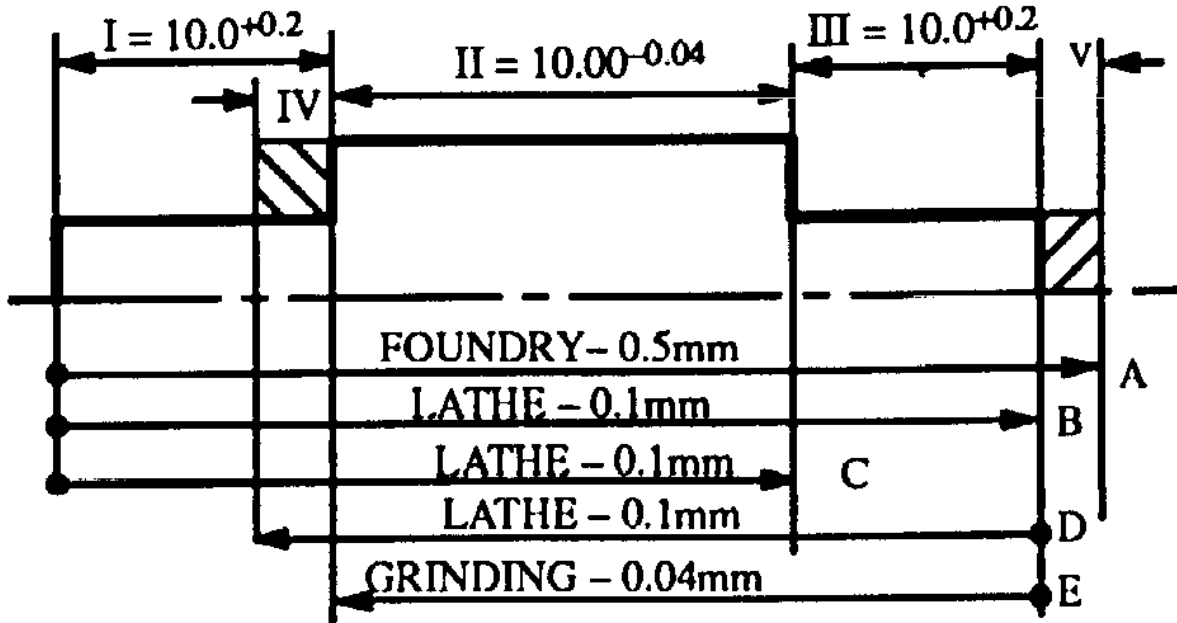


Fig. 8 - Normal Manufacturing Sequence

TOL (mm)	0.5	0.1	0.1	0.1	0.04			
Dim.	A	B	C	D	E			
	X	X				V		0.60
				X	X	IV		0.14
		X	X			III	0.20	0.20
		X	X		X	II	0.04	0.24
			X		X	I	0.20	0.14
						Dim	Dem Tol. (mm)	Res. Tol. (mm)

Fig. 9 – Calculation of the Resulting Tolerances

Repeating the focusing steps, the constraint is dimension II because the obtained tolerance is bigger than the specified one in the drawing.

The exploitation implies in making the best possible use of the available equipment, in this case, the grinding machine corresponding to operation E. That means to change the

manufacturing sequence as well as the fixtures so as to reduce the dimension chain. In this case the reference surface of operation E is changed elevating the constraint, as long as the obtained tolerance is not bigger than the demanded tolerance (Product Engineering). Fig. 10 shows the new manufacturing sequence.

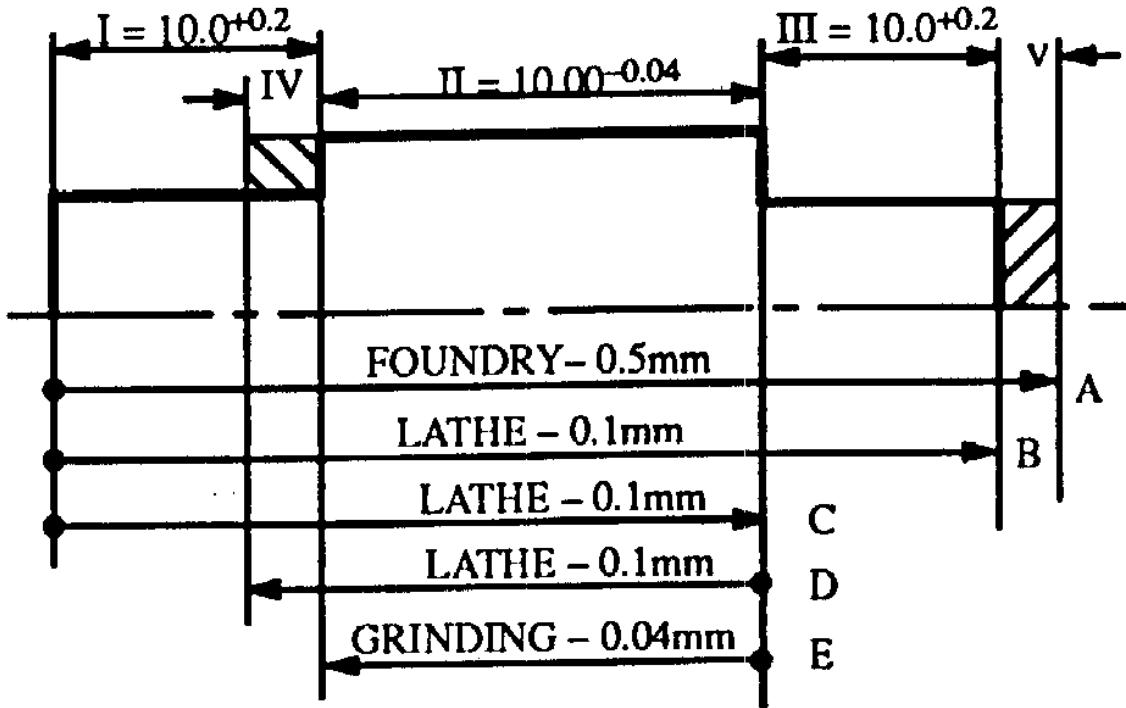


Fig. 10 – Focused Manufacturing Sequence

The subordination consists of calculating the tolerances of the other operations, to make the obtained tolerances not be bigger than the demanded ones, confirming the good results from the focused steps.

If still in this step it is necessary to elevate a constraint or perform a restrictive resource, in a better way, it should be acted on the equipment or choose the adequate one to perform the process, among the ones of the same group.

The continuous improvement is guaranteed by trying to identify the next constraint, to reduce rejects, long operations or ones with technical difficulties.

The result of the calculations of the working dimensions is shown below, for a depth of cut having 0.1mm of minimum chip thickness for the grinding operation, and 0.3mm for the turning operation.

$$\begin{aligned}
 A &= I + II + III + V = 30.35 \\
 B &= I + II + III = 30.18 \\
 C &= I + II = 20.08 \\
 D &= II + IV = 10.58 \\
 E &= II = 9.98
 \end{aligned}$$

RESOURCE CONSTRAINT ANOTHER
SUB-SYSTEM

When there is an accumulation of operations in certain equipments because of their accuracy or because of any other reason, there can occur a bottleneck, if their demand is bigger than their capacity. In this case, it is important to proceed an offload, so these operations can be executed by other less adequate equipments, but idle ones. This proceeding is equivalent to an elevation of the resource constraint helping in the attainment of the goal. The best way for this certainly applying the functional approach and the other steps of the VA Job Plan. The COOMPARE method⁸ is especially useful in this case.

A powerful but not frequently used way of approaching the problem, is to assign the equipments when defining the process. So, when choosing the equipments and designing the necessary jigs and fixtures for the execution of the parts, it is necessary to consider both delivery dates and possible existence of bottlenecks.

HOW TO EVALUATE THE CONSEQUENCES OF THE PROPOSALS

It can be imagined a chain of possible effects resulting from the proposed actions, in such a way as to forecast and evaluate qualitatively the possible impacts caused by these proposals (fig. 11).

Tol. (mm)	0.5	0.1	0.1	0.1	0.04			
Dim.	A	B	C	D	E			
	X	X				V		0.60
				X	X	IV		0.14
		X	X			III	0.20	0.20
					X	II	0.04	0.04
			X		X	I	0.20	0.14
						Dim	Dem Tol. (mm)	Res. Tol. (mm)

Fig.11 – Focused Calculation of the Resulting Tolerances

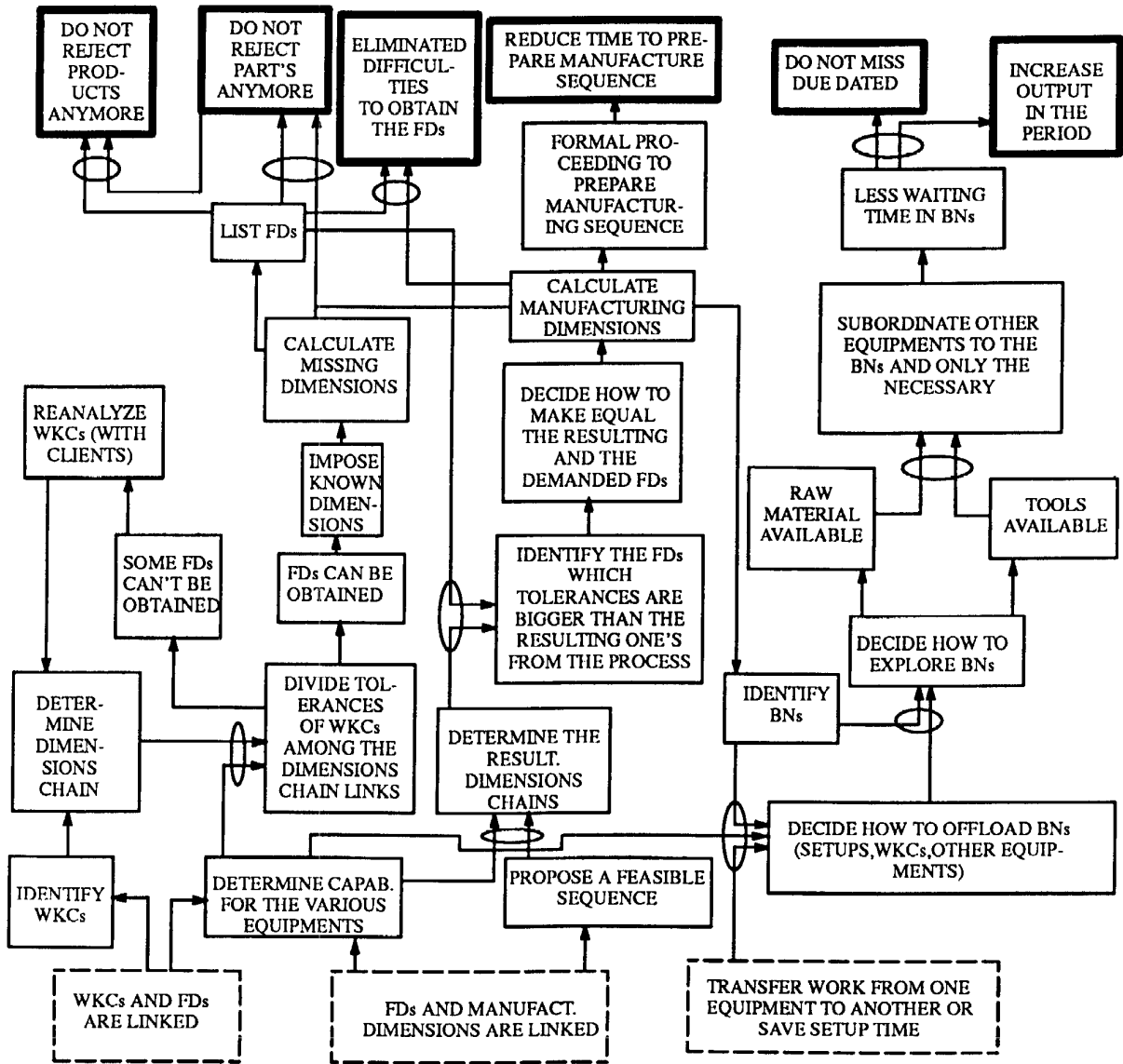


Fig. 12 – Resulting Effects-Tree

CONCLUSIONS

As soon as the initially pinpointed problems are solved, there is an increase in value both for the manufacturer and for the user, accomplishing thus the purpose of VA.⁹

In the case studied, the manufacturer gains by no longer having rejected parts or problems in assembly, as well as not having delay in the elaboration of the process sheets.

For the user, customer or client, the value is also increased by lead time reduction, elimination of defective products and improvements in the WKC's.

The consequence of such actions will improve competitiveness, getting more market share and conducting the company to the direction of its goal.

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