LIUC - Università Cattaneo

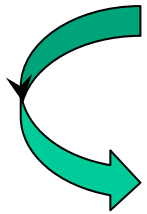
PROCESS CAPABILITY

Carlo Noè

Scuola di Ingegneria

e-mail: cnoe@liuc.it

❖ PROCESS CAPABILITY



The fundamental problem in order to **ensure the respect of design in the production process** is the choice of a "capable" production process

- able to allow the achievement of the aforesaid purpose
- not overlooking the fact that the results may vary (even in the case of parts produced consecutively and/or automatically!).

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Each process is characterized by its **Industrial tolerance** that can be determined through a systematic investigation.

The **Industrial tolerance** of a process depends on several elements (the technology used, the material being machined, the tools used, the operator) that contribute to determine the final result.

The comparison between the Industrial tolerance and **Project Tolerance** sets (specifications) evaluates the capability to process and decide accordingly whether or not to use it for the operations to be performed.

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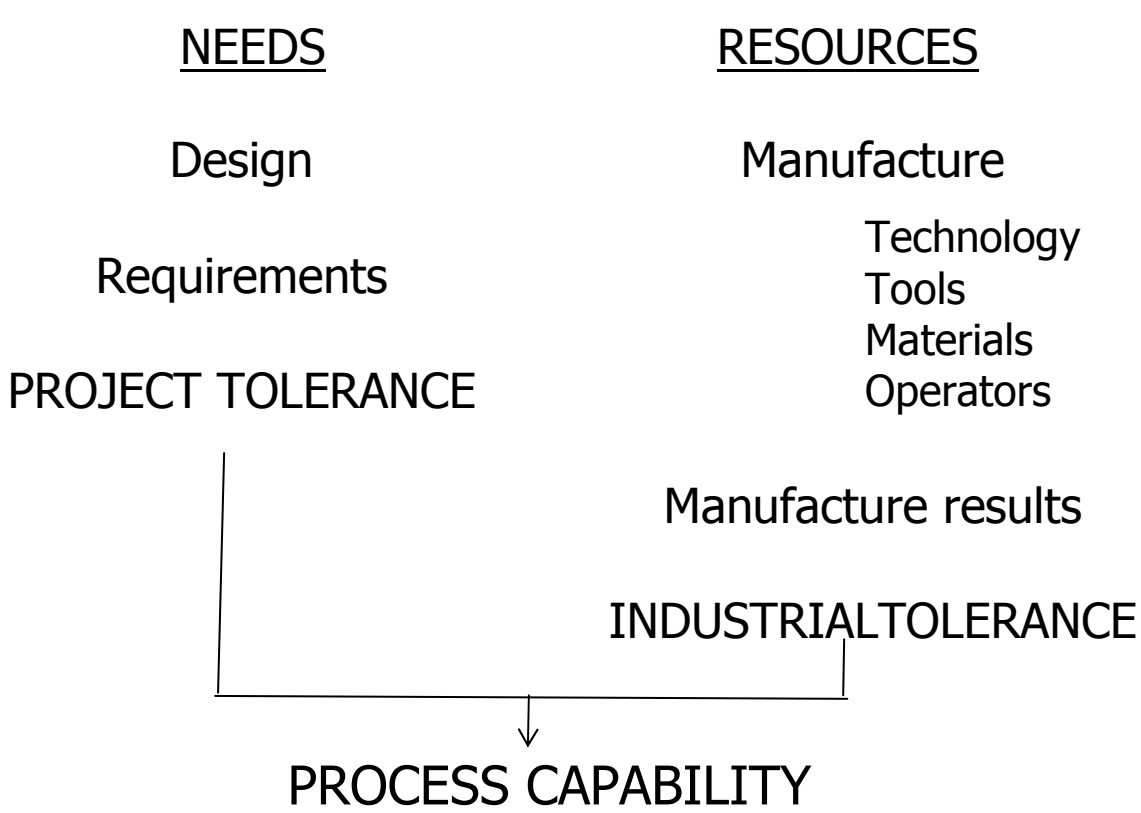
Process Capability evaluation scheme



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The process capability (**PC**) is the parameter that sets the limits of a production system in comparison to the compliance with the specifications of parts made:

PC=requirements (project tolerance range)/result (result tolerance range)

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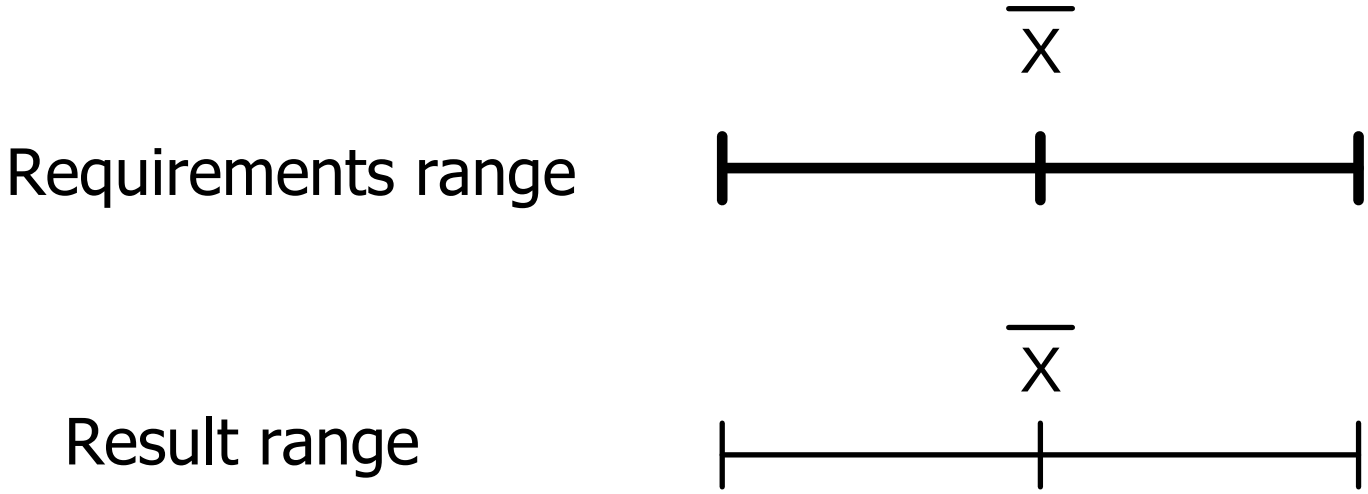
If **PC =1**, the range of results found equals to the range of the required tolerance.

Assuming that the average value is coincident, there will not be production of waste.



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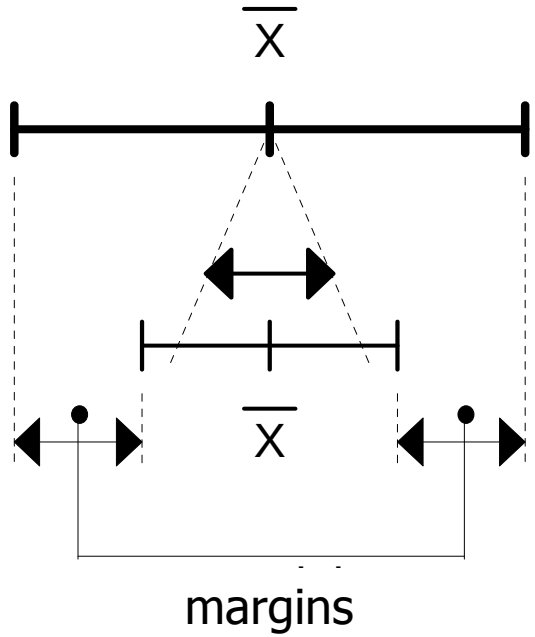
If **PC >1**, the range of results found is smaller than the range of the required tolerance.
The requirements will be respected.
Possibility of recovering margins of productivity.

Requirements range

Result range



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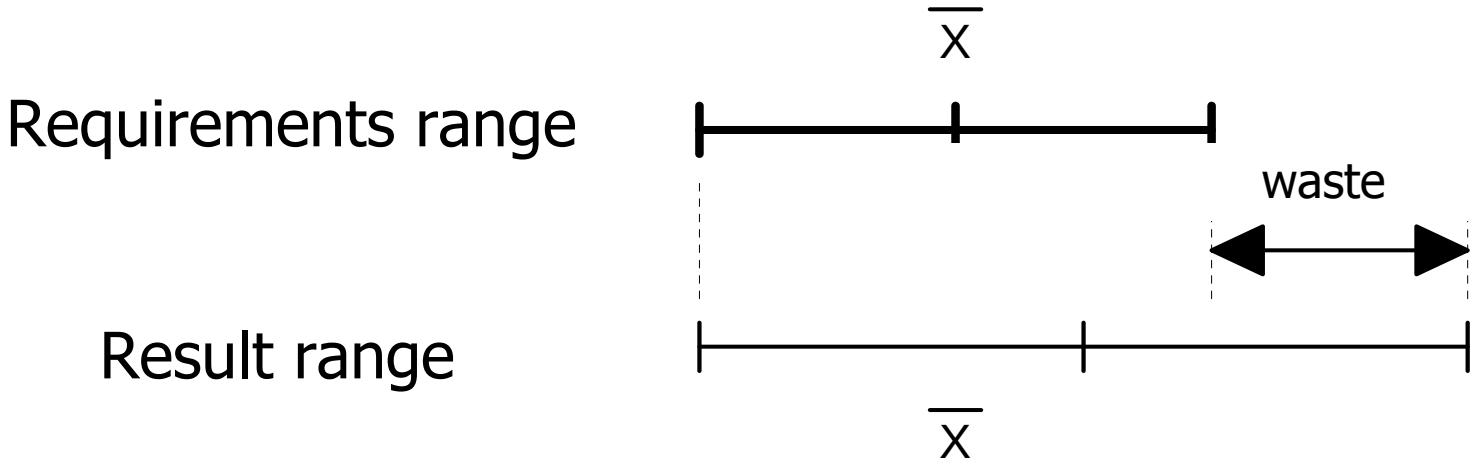
If **PC<1**, the required tolerance range is smaller than the range of results tolerance.
There will be production waste, depending on the variability of the
frequency distribution.



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HOW THE VARIOUS FACTORS CONTRIBUTE TO DETERMINE THE INDUSTRIAL TOLERANCE RANGE?

- Each **operating machine** (technology) which is used is characterized, due to its manufacturing process, by its own **natural tolerance** (precision).
- The **working materials** generate variability in the results because they are not entirely **uniform**.
- The **tools** used are subject to wear and tear; accordingly the results deviate in time in function of the law of wear. As it must be chosen, or designed and known the law of wear, manufacturing tolerances of the tool can be assigned so as to bring the industrial tolerance at the same level of tolerance of the project.
- The **workforce (operator)** ….. not to be considered now.

❖ INDUSTRIAL TOLERANCE

Natural tolerance

The natural tolerance expresses the variability that characterize a production system or a machine to operate within a specified tolerance range, without any manual corrective action, and considering the performance of the system or machine is not affected by exogenous factors.
By convention, we assume that the natural tolerance has a width equal to:

$$T_{nat} = \pm 3s$$

Where **s** = standard deviation around the mean

In **± 3s** the 99,73% of the production is included.

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Material mean variations

They can be due to:

- irregularity of the shape and size,
- mechanical properties,
- chemical composition,
- humidity rate,
- ….

Cause a variability V with a standard deviation from the mean value v such that V = ±3V includes 99.73% of what is produced.

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operating machine	⇨	natural tolerance
operator	⇨	
material	⇨	material mean variation
tool	⇨	tool construction tolerance
wear	⇨	wear mean values deviation

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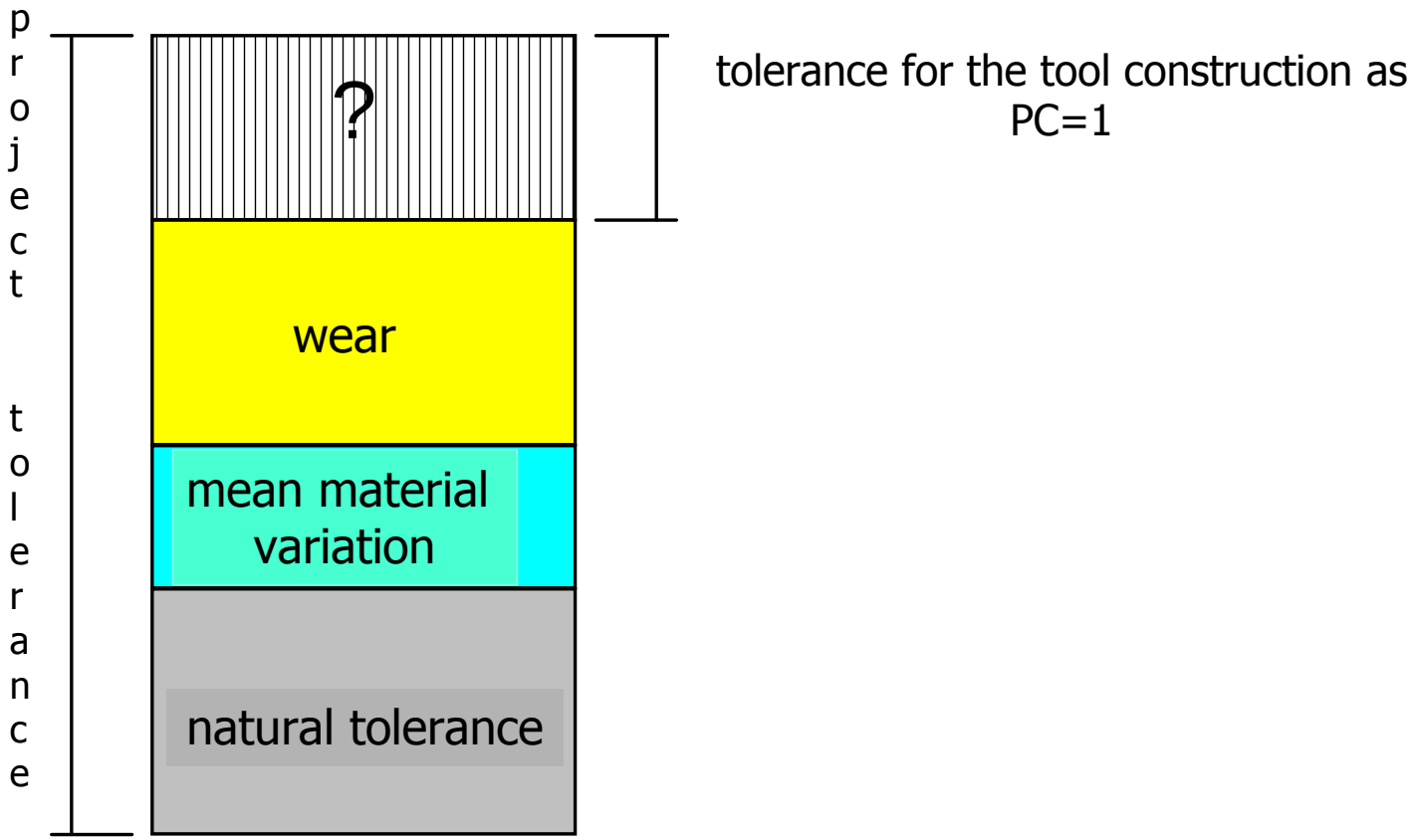
The components of the industrial tolerance in comparison with the tolerance of the project.



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Tool tolerance of construction

It means that in the construction design will assign the appropriate tolerance range to the tool.

Then all the tools within tolerance will be accepted. Of course, the measure most likely will be the central one, the others will be less and less likely as those corresponding to the extreme values according to a Gaussian distribution.

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Due to the phenomenon of systematic drift, results tend to vary with the cumulative volume of production achieved by the same tool/machine subject to wear.

In the definition phase of industrial tolerance the components "natural tolerance", "average variation of the material" and "tolerance of construction of tool" shall be considered to be constant in relation to the cumulative volume of production.

The effect of wear on the other hand is zero when the tool/machine is new and growing in a regular manner with the volume of production, at least until the tool/machine collapses.

At n-th production the effect of wear will cause the value of tolerance industrial to be equal to that of the tolerance of the project.

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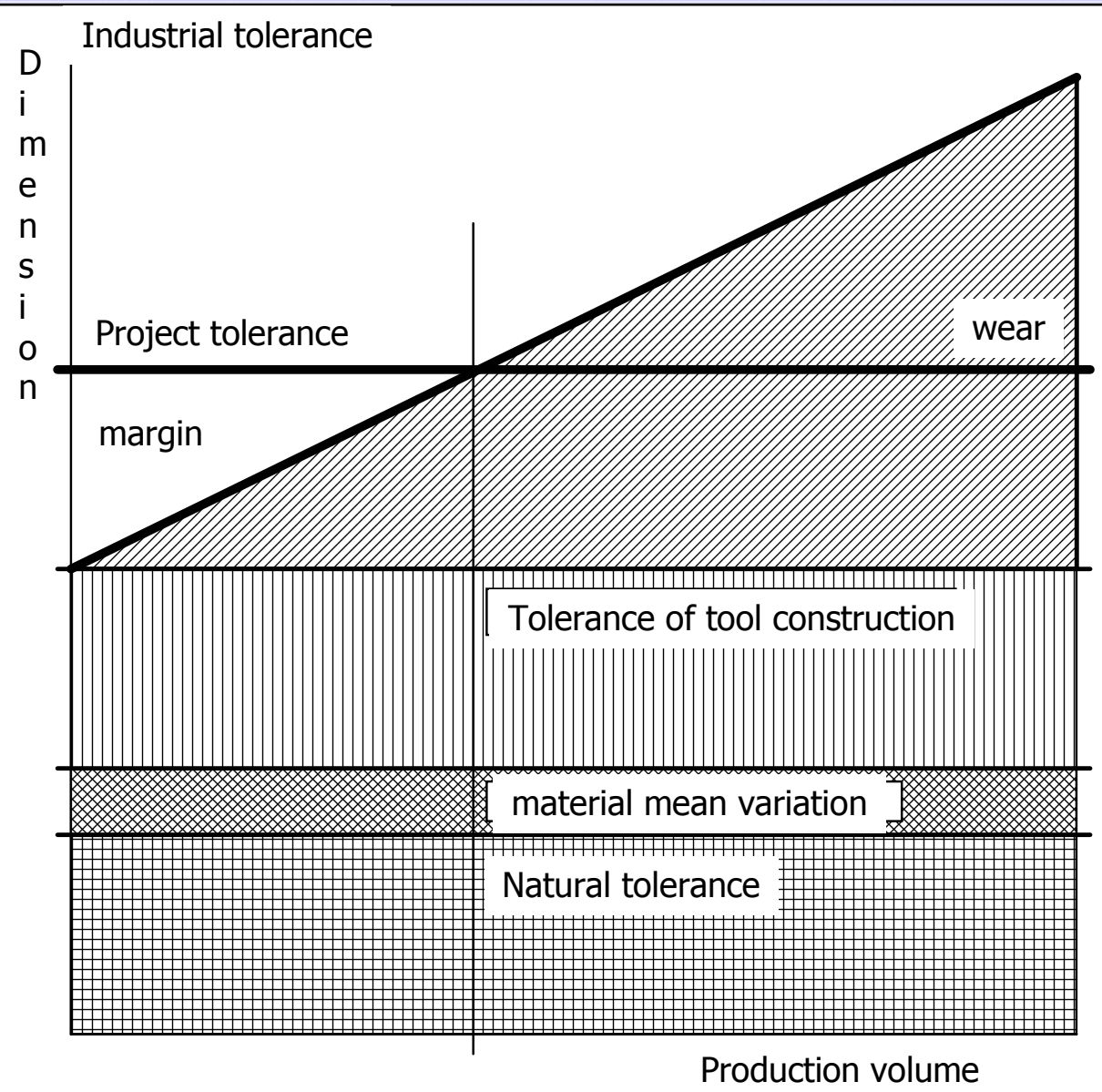

In the definition phase of industrial tolerance the components "natural tolerance", "average variation of the material" and "tolerance of construction of the tool" shall be considered to be constant in relation to the cumulative volume of production.

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The band that represents the component of "natural tolerance" indicates that the result (if it were up to this only component) may vary a range of values bounded by the two extremes, with a probability of having any value according to a Gaussian distribution. The same for the other two components "mean material variation" and "tolerance of construction of the tool."

Given that the three distributions are the same type, the amplitude of the possible variation of the result of the sum of the three bands always with a probability of having any value according to a Gaussian distribution.
Moreover, the wear effect that, as can be noted in the case illustrated by the chart below, does not change the distribution curve
but raises the probability lower and upper limits of the range.

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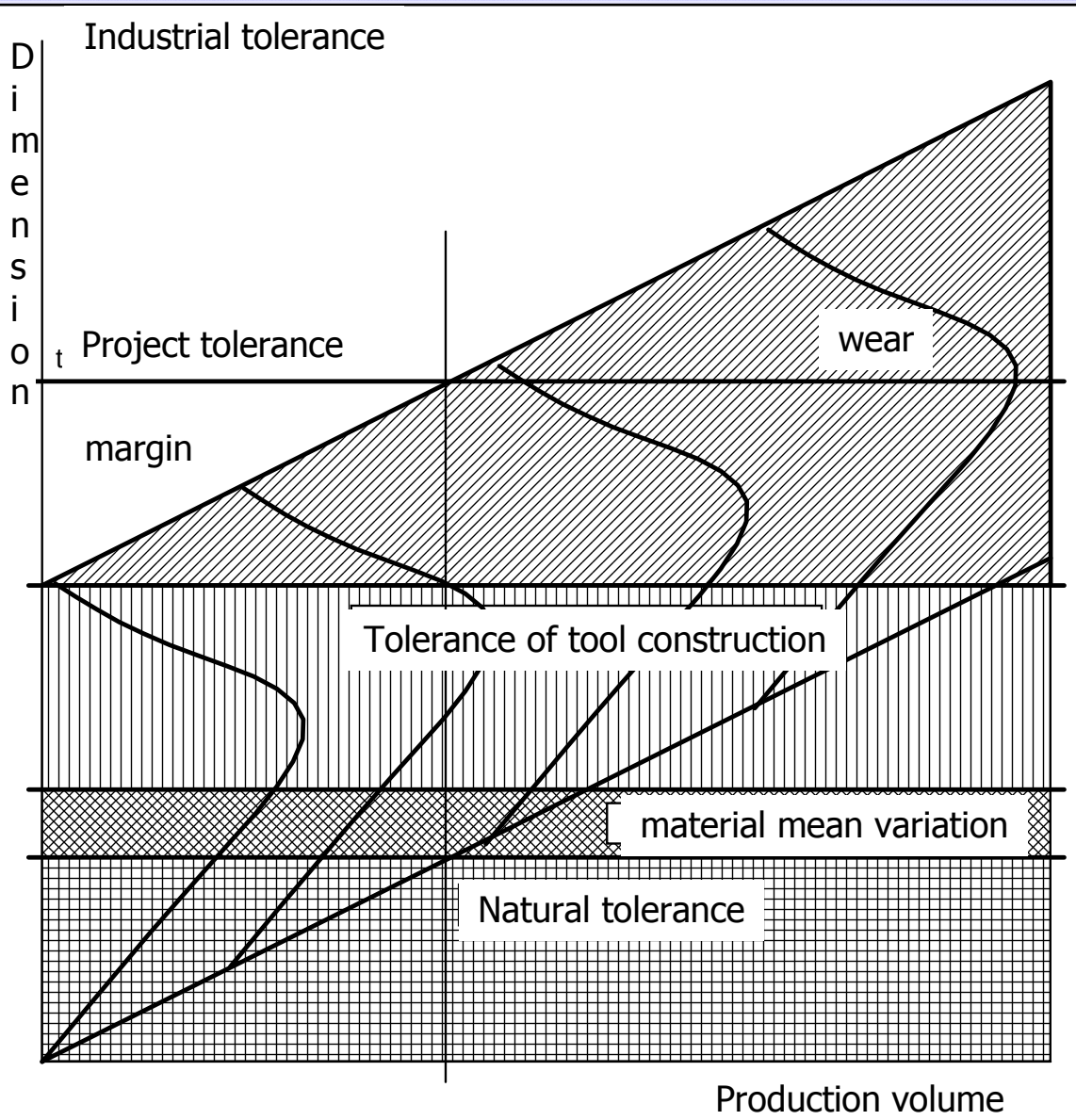

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What happens when you get the n-th production?

By the n-th production one end of the result distribution curve is likely to correspond with one of the ends of the project tolerance of the project.
So the n-th production is still responding the specifications, but the n-th + 1 production (as the progressive raise of the upper limit of the industrial tolerance and the resulting exceeded of the upper limit of the project tolerance) likely not comply with the specifications, with a likelihood equal to area of the corresponding Gaussian curve bounded by the upper level project tolerance.

How should we proceed?

It will be necessary to decide whether to continue with the same tool accepting an increasing likelihood of having production scrap or replace the tool and start again from the initial situation.

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The improvement of process capability is due to the reduction of the industrial tolerance.

Each element of industrial tolerance depends on several company areas or corporate entities which have to intervene with well-defined objectives.

elements	company areas	areas of intervention
Natural tolerance	methods, maintenance	work cycle, machine characteristics
Material mean variation	purchases, suppliers, inbound quality control	raw materials quality, supplier reliability, checks and tests skill
Tolerance of tool construction	design, toolroom	dimensioning, manufacturing precision
Wear	design, treatments	material selection, heat treatment

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Operator effect

The operator in principle does not affect the amplitude of the results, or rather its behavior is normally not similar to that of other components.

However, since it is the operator adjusts the machine, he can affect the range of variation of the result on the scale of the measured quantity.

The not desired result is that even if the process was capable, errors that the operator can make can generate production waste.

The range of variation of the result can be placed with at least one extreme value not in the range of tolerance of the project, although it can be completely inside.