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Capability Database of Injection Molding Process— Requirements Study for Wider Suitability and Higher Accuracy

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Abstract

Generally, there is little disagreement that an early consideration of dimensional accuracies achieved in production is conducive to the success of development of injection molding products. While different process capability databases (PCDBs) provide guidance for a meaningful estimation of the expected part variation, the adoption of corresponding guidelines and (proprietary) software tools seems to be, however, limited in industrial practice so far. This research paper addresses the gap between the available PCDBs and the requirement of designers in practice and investigates the key drivers for an improved applicability of corresponding database solutions in an industrial context. A survey of database users at all phases of product value chain in the plastic industry revealed that 59% of the participating companies use their own, internally created databases, although reported to be not fully adequate in most cases. Essential influences are the suitability of the provided data, defined by the content such as material, tolerance types, etc. covered, as well as its accuracy, largely influenced by the updating frequency. Forming a consortium with stakeholders, linking database update to technology changes and connecting dimensioning standards to database offerings are proposed solutions.

Keywords: Process capability database, injection molding, process variation, tolerance standard

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INTRODUCTION

Injection molded plastics have a significant presence in many products nowadays. Particularly used in high volume production [1], the corresponding injection molding processes thereby require an early consideration of the expected production accuracy to avoid cost and time-intensive revision of parts as well as of the capital-intensive moulds or machine set-ups in later product realization phases.

For this purposes, numerous support tools which provide data on the expected variation of injection molded components were conceived over time and used in today's design practice. Provided in a variety of formats, such as internal guidelines, standards or database solutions hereinafter unanimously referred to as process capability database (PCDBs), the provided data is an invaluable source of information for various tasks during the product development cycle.

At the plastic part design stage, they:

1. Serve as a guide for the use of geometric controls.
2. Support accurate Design for manufacturing.
3. Help designers to distribute fixture and part interfaces.
4. Allow for initial product cost estimation.

At the mould developments stage, they:

5. Set the benchmark for mould design performance, allow to meet the plastic part standards instead of being limited to drawing specifications.
6. Direct the application of mould design strategies.

And at the plastic part production stage the provided data allows to:

7. Set a benchmark for production performance.
8. Extract suitable operational conditions from database and applying for better accuracy.

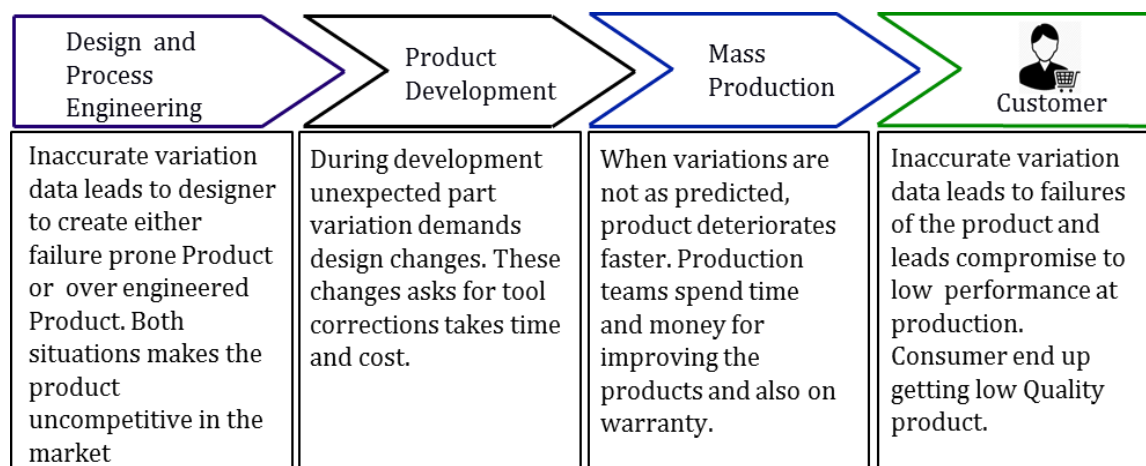


Fig 1: Impact of Inaccurate Variation Estimation.

A systematic use of PCDBs consequently helps to ideally eliminate many of the product revisions that would have arisen due to unexpected production variations, hence to avoid negative impacts on various stages of product development and use (Figure 1). Furthermore, PCDB also ensures that designers and manufacturing experts as well as the original equipment manufacturer (OEM) and suppliers share a common understanding on variations.

At the same time, the adoption of corresponding PCDB solutions seem to be, however, limited in industrial practice. While in the early days of injection molding development, PCDBs were mostly established by standards organizations (DIN 16901 in 1973, SPI in 1965, etc.), the process capability of injection molding has improved significantly due to technology advancements over the last decades.

As the effects of plastic raw material development, molding machine development, mould design, progressed however at a different pace in various parts of the globe, the standard PCDBs are heavily challenged for being up-to date. This created a gap between the user requirement and the offering of standard PCDBs which has led many organizations to work on their own databases, limited to only their products, over the years.

This research focuses on understanding which databases the plastic industry is using and how extent users found them suitable and accurate also identified the gaps and possible solutions.

The remainder of the paper is organized as follows. First of all, methods section describes the research methodology and points out how a review of literature on PCDBs has led to the conducted industrial survey. The survey findings and potential solutions are presented afterwards. Paper closes with a discussion on implementation challenges and conclusion.

METHOD FOR FINDING GAPS AND SOLUTIONS

Concept of capability databases and Injection molding process are started early 20th century. It is considered that deeper study of literature only gives the right direction to understand PCDB characteristics. At the same time, listening the current engineer who is expected to use PCDB is required to find the gap. The research process used to investigate current industry conditions, gaps and solutions is shown in Figure 2.

LITERATURE REVIEW

A systematic literature review involved journals, conference proceedings, academic publications, industry practices, books, patents, thesis, social media, from the host university database, Web of Science, Scopus, Google scholar, LinkedIn, and open internet sources. Aim is to understand the process of building data bases followed by their growth and industry acceptance.

Backofen (1961) [2] defined a process of collecting process capability data from polycarbonate parts. He was able to relate dimensional variation with the weight of the part in a semiautomatic production setup.

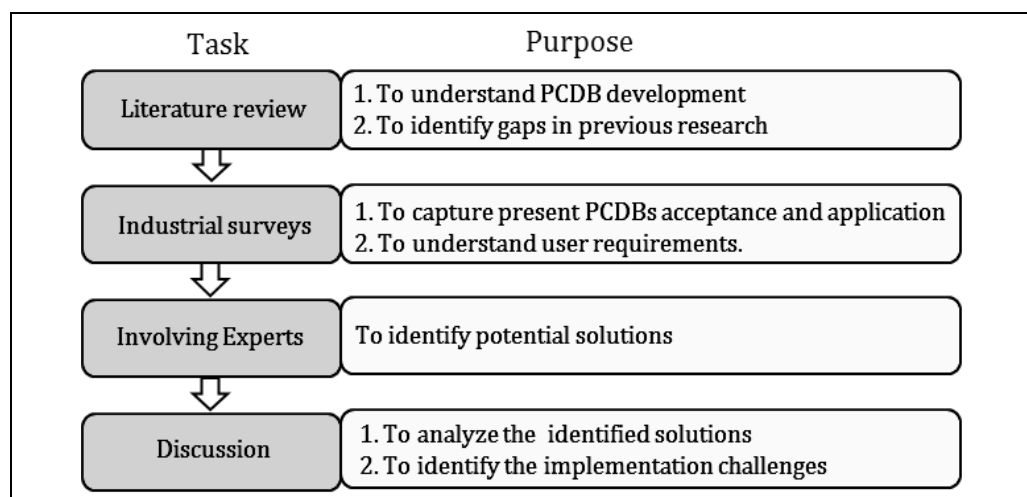


Fig. 2: Step-by-Step Process to Understand the Requirement, Gap and Solutions.

Erhadr G (1966) was able to relate injected part tolerances to International Tolerance (IT) grades and provided a guide for designers to estimate variations from process parameters. DIN (German Institute for Standardization) [3] released plastic molding tolerances with DIN 16901 in 1973, updated in 1982; In 2013 it was replaced by DIN 16742 which included more geometrical tolerances, suitable for any material and also with various production standards. Standards and Practices of Plastic Molders (SPI) [4] provided a tolerance guide for designers first in 1965, updated 1998 by referring a part by means of specific geometric control variations, instead of only linear. A process for converting measured data to process capability was patented by Dougherty, *et al.* (2002) [5].

Being generic, the process can be used to injected plastics too. Daniel (2003) [6] emphasized the importance of data reliability and the designer's confidence for higher acceptance of PCDB. Thornton (2004) [7] highlighted how important it is for PCDB to be presented in the way that designers can use. Kevin and Phelan (2006) [8] described the designer's requirements of PCDB, in terms of easy ways to search and read the data. Kevin and Phelan (2009) [9] also explained, how PCDB helps new generation of designers to understand the process impact on product variations. Okholm *et al.* (2014) [10] described the clarity required in PCDB data and designer orientation. Eifler *et al.* (2014) [11], discussed on the requirement of considering product characteristics while

generating PCDBs. They identified an opportunity for shifting the design methodology from *design for tolerance* to *design for process capability*.

Melissa *et al.* (1999) [12] research on PCDB usage, detailed the data acceptance of designers and gaps between data generation and usage. Their survey shows that a very small percentage of designers use the data. Lack of management strategies and focus on PCDB were identified as main reasons.

KEY FINDINGS

Literature shows that capturing production achievement as process capability to use at design is initiated by various industries at the beginning. Standards organization identified the requirements of PCDB over the industry growth. Identification of designer needs, generation change impact, and generalizing methods for wider applicability of PCDB is evident since 2000. These indicate the increasing gap of designer requirement and PCDB offering.

However there is no evidence that previous researches evaluated the effectiveness of PCDBs. The root causes for PCDB not being used uniform across the plastic industry is not known. An extensive survey attempted to find them in this research. An industrial survey conducted by Melissa M Tata and Anna C. Thornton (1999) focused on generic PCDB for any kind of process, looked at PCDB strategy from a management perspective, specific to

the data base generated within the organization. Daniel Kern’s survey (2003) intended to capture the generic PCDB status in the American automotive industry. This survey (2015–16) focused on the plastic injection molding process, looked at end user perspective, to measure standard and internally developed databases usage.

Industrial Surveys

Desired and current status of PCDB is well stated by Melissa M Tata from industrial survey as “establishing tolerances and key characteristics for a product “,”Lack of trust and understanding of data”, “poor population”, “data pertinent to design not available”, etc. Daniel C Kern survey reveals similar facts. Relating those outcomes to PCDB suitability and accuracy survey questions prepared in user point of view.

Plastic engineer’s prediction requirement changes on plastic material, size, type of geometric control, and production quality level. Engineers working with limited materials and fixed menu products may need only a few tables from PCDB, but the same database may be found unsuitable for engineers dealing with different materials and products across different industries, like automotive, domestic appliances, medical equipment, etc. Some engineers need precise geometrical controls over and above linear, like straightness, flatness, parallelism, position, profile, etc. When PCDB offers only a few tolerances, its suitability reduces. When accuracy requirements are high, engineers opt for high quality production systems. Similarly low quality systems deal with lower

accuracies. If PCDB does not offer variations for various process conditions, the users will not be able to find data related to their production standards. When operations extend to continents, there is a need to deal with different levels of production standards, and users will need to connect variation to process conditions. Similarly, when the product portfolio increases, then many materials and different sizes and geometries will be required by the engineer.

Survey questions and interpretations are shown in Table 1. The survey covered product designers, mould makers and production houses, and also covered varied product and operational complexities. Surveys were conducted through Google forms, LinkedIn forums, and individual interactions through e-mail, telephone and in person. Questions on product and operational complexity are to understand the user requirements and connect to their opinions of suitability and accuracy.

Survey Statistics

Survey aimed to cover users of varied requirements in different industries. Table 2 and 3 show the configuration of 46 survey participants. First PCDB usage, Suitability and accuracy questions data has been studied to understand the industry status. Impact of product and operational complexity and updating frequency are analyzed.

More than half of the participants use their own internal database, as standard ones do not suit them. An internal database can show only their own past products data, so the challenge relating to new kind of products is evident.

Table 1: Summarized survey questions and interpretations.

	Intent	Question focus	Interpretation
1	Capturing Usage	Which PCDB is in use? a. DIN b. SPI c. Others. ____ d. Internal database d. None	1. Standard databases shows acceptance of different PCDBs available. 2. Large companies make their upon internal, when they found standard databases are not suitable 3. None categories depend on their mould maker or resin supplier.
2	Capturing Suitability	Suitability: How extent database matches to your application? a. High b. Medium c. Low	Higher matching shows the PCDB coverage of materials, process conditions and also type of tolerances user need.
3	Capturing Accuracy	How accurate your PCDB to actual production? a. High b. Medium c. Low	1. Higher accuracy shows the PCDB updation with technology changes. 2. Internal PCDBs also may show less matching due to the time lag between data captured, applied and recaptured.

4	Capturing Technology Alignment	How frequent your PCDB updated? <i>a.</i> Every year <i>b.</i> Every 2 years <i>c.</i> Every 3 years <i>c.</i> Every 4 years <i>e.</i> Every 5 or more years	1. Higher frequency gives higher alignment with technology changes also improve accuracy. 2. Internal data can be maintained easy for higher frequency.
5	Capturing Gaps	Top three improvements you want to be in your PCDB? 1. _____ 2. _____ 3. _____	Gaps between user and their database
6	Capturing Product Complexity	How do your products vary in size, material and accuracies? <i>a.</i> Use more than 10 materials - YES/NO <i>b.</i> Size difference of smallest and biggest part is >500 mm - YES/NO	1. Plastic materials using more than 10 are complex 2. Size variation is more than 500 mm is complex
7	Capturing Operational Complexity	How spreads are your operations? <i>a.</i> Local - Customers are within same continent <i>b.</i> Multinational - Customers are more than one, but development is within one continent <i>c.</i> Global - Development centers are at more than one continent	1. Local -Shows the application challenges are limited. 2. Multinational - Application need to satisfy varied customer demands. 3. Global - Varied application, varied demands and multiple practices.

Table 2: Type of Industry and their Product Development Stage.

	Product development stage		
	Part design	Mold development	Part production
Automotive	14		7
Medical	4		
Aerospace		1	
General	7	5	8

Table 3: Continents of the Participants and their Product Contribution Level.

	Product Level		
	OEM	Tier 1	Tier 2
NA	2	6	11
EU	3	6	
ASIA	5	11	2

Internal database: Many organizations maintain their own dimensional achievement from previous projects as their capability. The type of materials and kind of geometries are limited to their products. These organizations are observed to be with less complex products, and multinational and global in operations.

DIN: Deutsches Institut für Normung offers plastic part tolerances with the DIN16742 standard. Many engineers are still using the old version, DIN 16901. This category contains all kinds of operational and product complexity with medium accuracy.

Some OEMs adapted this standard into their own standards. Some European and Asian countries accepted it and referred in their own standard.

SPI: Society of plastic industries offers tolerance tables for all major materials with limited geometric controls. These users are global in operations. Many tier2 service providers offer the accuracy of the SPI tables.

Do not use any: Most of these are local, and tier2 service providers. They are believed to work to meet drawing specification, irrespective of any PCDB. Some of them considered that none of the available PCDBs are acceptable.

Survey Findings

PCDB Usage

Figure 3 shows the user preference.

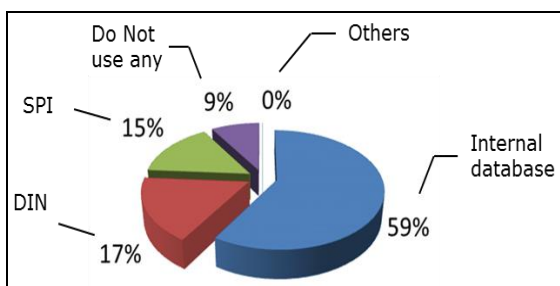


Fig. 3: Percentage of PCDBs in use.

PCDB Suitability

Figure 4 shows user understanding of PCDB suitability to their needs. This indicates the coverage of PCDB data for all the materials they use and all the geometric controls they apply.

Low suitability: Out of all PCDB users 38% found suitability is low. Most of the standard database users are in this category.

Medium suitability: 57% considered their database is suitable to medium level. The majority of internal database users are in this category.

High suitability: Only 5% found their database is suitability is high enough to their requirements. This segment comprises internal database users only.

Suitability is influenced by product complexity. Table 4 shows the responses of suitability against product complexity criteria. Increase in product size variations and number of materials in use, reducing the suitability. Improvements suggested by users, listed below also supporting this data.

- More and precise material grades to be covered
- Applicability to all geometries is required
- All type of tolerances to be offered

PCDB Accuracy

Figure 5 shows users finding on their PCDB values matching to actual production achievement.

Low accuracy: 33% of users found their PCDB values matching to production are low. Most of these are standard database users.

Medium accuracy: 62% of users found accuracy to medium level. Most of these are internal database users.

High accuracy: Only 5% of users considered their database highly accurate to their production data. All of these are internal database users.

Operational complexity found influenced on accuracy. Table 5 shows the responses of

accuracy against operational complexity criteria.

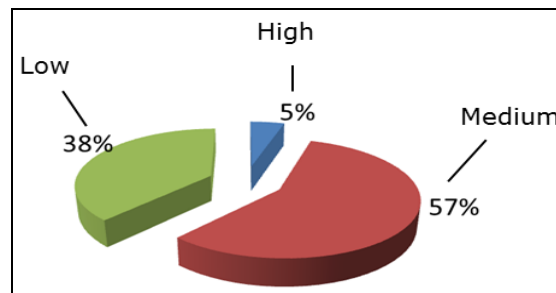


Fig. 4: How Users Found their PCDBs are Matching to their Everyday Application.

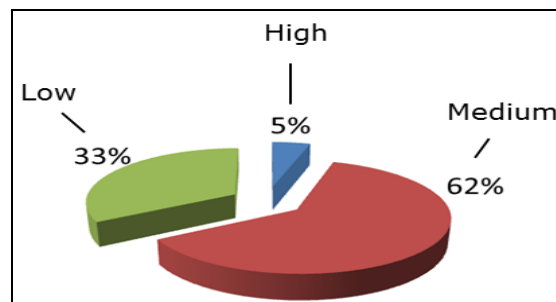


Fig. 5: Responses of PCDB Accuracy.

Table 4: Suitability Shift Over Product Complexity Change.

		Suitability		
		High	Medium	Low
Parts size variation	<500	2	13	0
	>500	0	11	16
Number of materials in use	<10	1	9	6
	>10	1	15	10

Table 5: Accuracy Shift Over Operational Complexity.

		Accuracy		
		High	Medium	Low
Local		0	15	2
Multinational		1	5	6
Global		1	4	8

Operations expanded to more regions deals with varied production practices and achievements. When PCDB generated process specifications do not match to the operational standards, values also do not match. Improvement suggested by users listed below is supporting this data.

- PCDB generated process details to be specified.

- Level of various production quality to be linked.
- Type of machinery and controls to be linked.

PCDB Status

The numbers above cannot stand alone as the limited number of samples taken creates some uncertainty. Based on the results and probability estimation of proportions with a 90% degree of confidence the true values through the Eq. 1 are expected to lie within the intervals shown in the Table 6.

$$P \pm Z_{(1-0.9)} \sqrt{\frac{P(1-P)}{n}} \quad (1)$$

With the above estimation intervals, PCDB usage status can be stated as “59% of Injection molding industries use their own internally made database with medium suitability and accuracy”.

PCDB Updating Frequency

Figure 6 shows user awareness of their PCDB updating frequency.

Every year: 5% of users confirmed their PCDBs are updated every year. All these are internal database users.

Once in 2 years: 19% of users mentioned their PCDB gets updated every two years. All of these are internal database users.

Once in 3 years: 12% of users know their PCDB update happens once every three years. All of these are internal database users.

Once in 5 or more years: 64% of users say their database gets updated every 5 or more years. All standard database users are in this segment.

A directly proportionate relationship between data accuracy and suitability with updating frequency is evident through the data. Table 7 shows the change in suitability and accuracy against updating frequency.

This lead us to understand updating frequency in equally affecting suitability and accuracy, in turn linked to all user conditions of product and operational.

PCDB Gap Analysis

Survey results summarizing that suitability depend on materials and geometric tolerances offered by PCDB and accuracy depends on offering various process conditions and technology levels. At the same time, PCDB updating frequency is affecting all of these. Table 8 shows two aspects of suitability and accuracy are sub divided into four basic concerns. All are found related to four PCDB attributes.

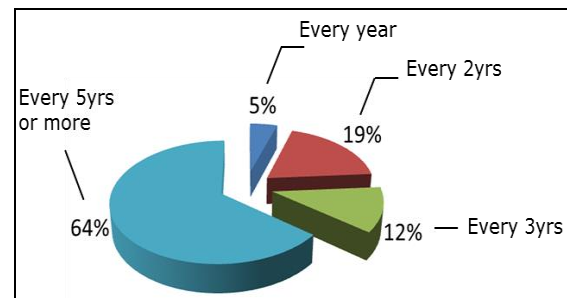


Fig. 6: Updating Frequency Distribution. No Response Found with once in 4 Years Category.

Table 6: Calculation of Confidence Intervals on Survey Findings to Reduce Data Uncertainty.

	Survey finding	Lower confidence level	Upper confidence level
Usage of Internal database	59%	47%	71%
Suitability found Medium or high	62%	46%	78%
Accuracy found Medium or high	67%	55%	79%

Table 7: Suitability Reduces with Lowering Frequency.

	Suitability			Accuracy		
	High	Medium	Low	High	Medium	Low
Every year	2	0	0	2	0	0
Every 2 years	0	8	0	0	7	1
Every 3 years	0	4	1	0	4	1
Every 4 years	0	0	0	0	0	0
Every 5 or more years	0	12	15	0	11	16

Table 8: Gap Analysis.

User Concerns		PCDB Generating Process Attributes			
		Materials Covered	Tolerances Offered	Production Standards	Updating Frequency
Suitability	Latest materials	X			X
	Geometric tolerances		X		X
Accuracy	Process conditions			X	X
	Technology changes				X

Suitability-Latest Materials: From time to time new plastic materials come into the application. When PCDB does not offer the material of need, the design needs to pick the nearest one and compromise on the results.

Suitability-Geometric Tolerances: Some databases offer only linear tolerances, some offer limited geometrical tolerances also. When designers follow the dimensional tolerances, they expect all those geometric controls to be present in PCDB also, finding only a few gives partial suitability.

Accuracy-Process conditions: Variations are also connected to the production standards followed. Some PCDBs offer the data in levels of quality, allowing the engineer to connect his own production standard to variations. Not having this option, leads to low accuracy.

Accuracy-Technology changes: Process capability is improving with technology, which can be linked with time. PCDBs are found to be less accurate when their revisions are dated very long and reflect obsolete techniques.

Gap analysis led to four basic PCDB attributes, materials covered, tolerances offered, option of various production standards and updating frequency. PCDB generating process attributes need to be aligned to user needs and industry growth trends to address the concerns.

Materials Covered

All the base materials and their grades need to be covered in PCDB. In this global working environment, new materials are created at high frequency. PCDB will be able to address more materials by accepting the material properties, instead of the name. The dimensional achievement of any material is based on their

influencing characteristics, shrinkage, density, Melt Flow Index (MFI), etc. Materials identified with a range of characteristic values allows for defining any future material. This information is generated by plastic material developers. The PCDB generating process needs to identify plastic material experts as stakeholders and involve them in designing this attribute.

Tolerances Offered

Plastic part designers are directed by standards that apply on drawings to specify the product. A few are:

1. ASME Y14.5 Dimensioning and Tolerancing.
2. ISO 1101 Geometrical Product Specifications.
3. BS 8888 Technical Product Specifications, etc.

All these types of dimensional and geometric controls that designers use are to be provided in the database needs to be connected to the revisions of this standard. The PCDB generating process needs to identify dimensional standard organizations as stakeholders and involve them in designing PCDB tolerances offering.

Production Standards

Monitoring and control methods of production change the dimensional achievement. Production characteristics like environment control, degree of automation, molding machine accuracy, measurement instrumentation, etc. together defines the production level.

PCDB should allow the engineer to define production level by choosing their own conditions. The list of conditions and their impact nature are derived from experts from mass production units. The PCDB generating

process needs to identify the plastic part mass production industry experts as stakeholders and involve them in defining different parameters and their impact factors on variations. Connecting cost factors to production standards provides additional value to users.

Updating Frequency

The frequency of updating is influenced by three factors.

- Technology pace in mould and injection machinery accuracy.
- Frequency of new materials added to the industry.
- Update of Product specification standards.

PCDB updating is expected to be linked to every change of these influencers. A periodic updating mechanism set with all stakeholders matches to user expectations.

Database acceptability is also affected by “not knowing” the data capturing process. Users need to be communicated on the process conditions and the machinery used to prepare

the database such as, Injection molding method. Mould design strategy, moulding machine accuracies, mould quality specifications, measurement process, quality standards of production, statistical methods used, etc. All these are expected to be specified along with data.

SOLUTION

All processes for common ground are defined by a consortium with all the stakeholders. This consortium performs various experiments on each material on common ground and captures the variations. Using experimental data, they define all the characteristics and their relationship function into dimensions. By utilizing physical and virtual facilities of experiments variation tables can be generated for any material, and conditions for defined geometries and controls.

The same consortium decides on updating frequency, maintaining revisions and ensuring user education. A pictorial representation of the PCDB mechanism with all the stakeholders is shown in Figure 7.

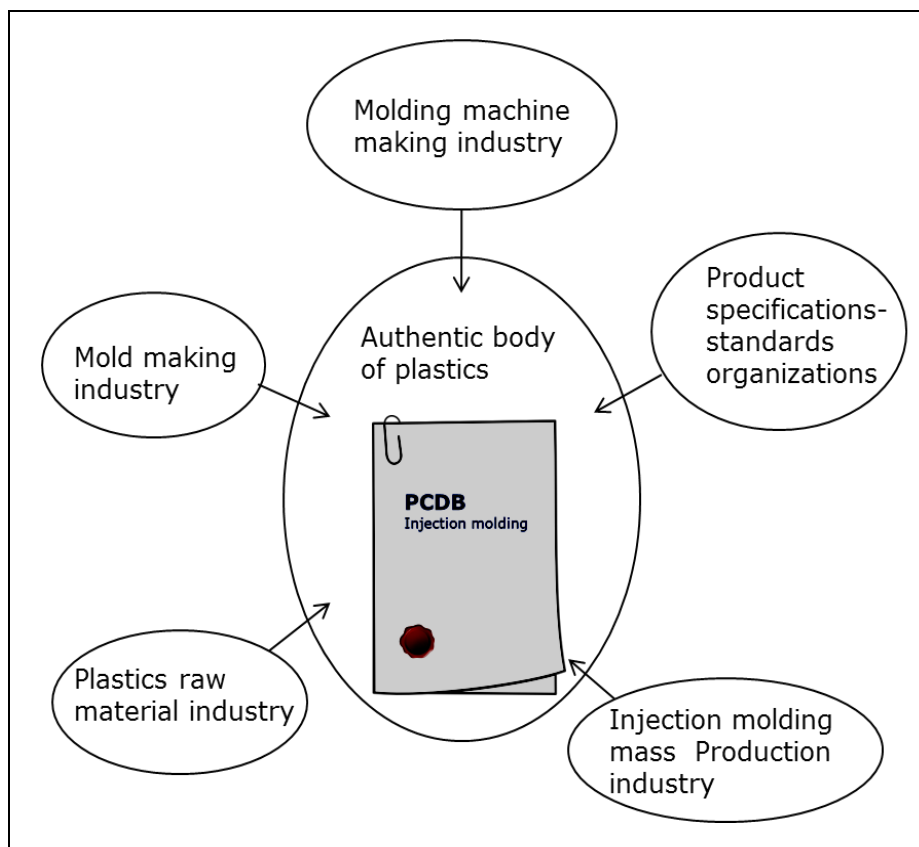


Fig. 7: An Injection Moulding Process Consortium for Making Wider Acceptable PCDB.

DISCUSSION

Challenges and opportunities have been discussed by plastic experts as part of survey on bringing more widely acceptable PCDBs.

- To make one central PCDB, alignment of technology developments including materials, machinery, and manufacturing is required. Many developments happen in pockets of societies. Many of these developments are indirect to the molding industry, and those are highly difficult to align. For example: new CNC machining technology has moved a step forward and is able to cut metals precisely, which improves mould accuracy. It influences the plastic part accuracy indirectly.
- Many plastic materials get developed in a customized environment for specific products, which are not common to all. Trade interest and intellectual property rights may reduce the opportunity of coverage.
- Many countries achieve different plastic accuracies, which are less known to rest of the world. Making them part of the global PCDB is a challenge.
- Generalizing geometries and making them suit every product geometry requirement carries unlimited combinations. For example: A cylindrical shape, can have several sub categories with small changes, adding a notch, adding a hole, adding a projection, etc. In every situation dimensional achievement will be different.
- As PCDB represents mass production estimation, users may found less accuracy in batch production situations. Additional factor may require for this segment of users.
- PCDBs are required to be measured by their “suitability” and “accuracy”. These metrics allows PCDB generating process to evolve and sustain. Metrics can be linked with plastic industry volume and growth statistical measures.

CONCLUSION

The process capability database has a significant role in the plastic product development process. Wider suitability and accuracy brings common understanding of tolerances in the injection molding industry. The global product development culture demands standards, allowing for better

communication and repeatability of any product anywhere. This situation stresses the requirement of generating robust PCDB, which is dynamic to adapt new materials, technology and dimensional standards changes. The latest database of DIN16742 has made a few steps in this direction, but many gaps are yet to be filled. PCDB for injection molding is to provide users the ability of variation estimation for any material, any process condition, and any type of tolerance application for any geometry.

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REFERENCES

1. Production of plastics worldwide from 1950 to 2015, *Statista* [cited 2017 April 10]; Available from: <https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/>.
2. Backofen W. Toleranzmessungen an Spritzgussteilen. *Kunststoffe*, 1961, Bd.51, Heft 11; 728–730p.
3. DIN 16742 Plastics moulded parts - Tolerances and acceptance conditions; Text in German and English, *DIN Standards Committee Plastics* [cited 2017 April 10]; Available from: <http://www.din.de>.
4. Standards and Practices of Plastics Molders, *Globalihs: Society of plastic industry* [cited 2017 April 10]; Available from: https://global.ihs.com/doc_detail.cfm?&item_s_key=00513479
5. Dougherty JJ, Campbell TR, Arvidson AL. Method for creating a process capability database. 2002; US Patent 6, 466: 927p.
6. Kern DC. Forecasting manufacturing variation using historical process capability data: applications for random assembly, selective assembly, and serial processing, *Doctoral dissertation, Massachusetts Institute of Technology*, 2003; [cited 2017 April 10], Available from: <http://hdl.handle.net/1721.1/29960>.
7. Thornton AC. *Variation risk management: focusing quality improvements in product development and production*. John Wiley & Sons, USA, 2004.
8. Delaney K, Phelan P. Refinements in using historical process data to optimize tolerance

- allocation, *Proceedings of the 23rd International Manufacturing Conference*, 30th Aug–1st Sep; Dublin; 2006.
9. Delaney KD, Phelan P. Design improvement using process capability data. *Journal of Materials Processing Technology*; 2009; 209(1): 619–7p.
 10. Okholm AB, Rask M, Ebro M, et al. Improving process capability database usage for robust design engineering by generalizing measurement data. *Proceedings of 13th International Design Conference*. 19–22 May, Croatia, 2014; 1133–12p.
 11. Eifler T, Göhler SM, Howard TJ. Design to Process Capabilities: challenges for the use of Process Capability Databases (PCDBs) in development. *Proceedings of the 25th Symposium Design for X*. Bamberg, 01–02 Oct 2014, 145–11p.
 12. Tata MM, Thornton AC. Process capability database usage in industry: myth vs. reality. *Massachusetts Institute of Technology*, 1999 [cited 2017 April 10], Available from: <http://hdl.handle.net/1721.1/84144>.

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