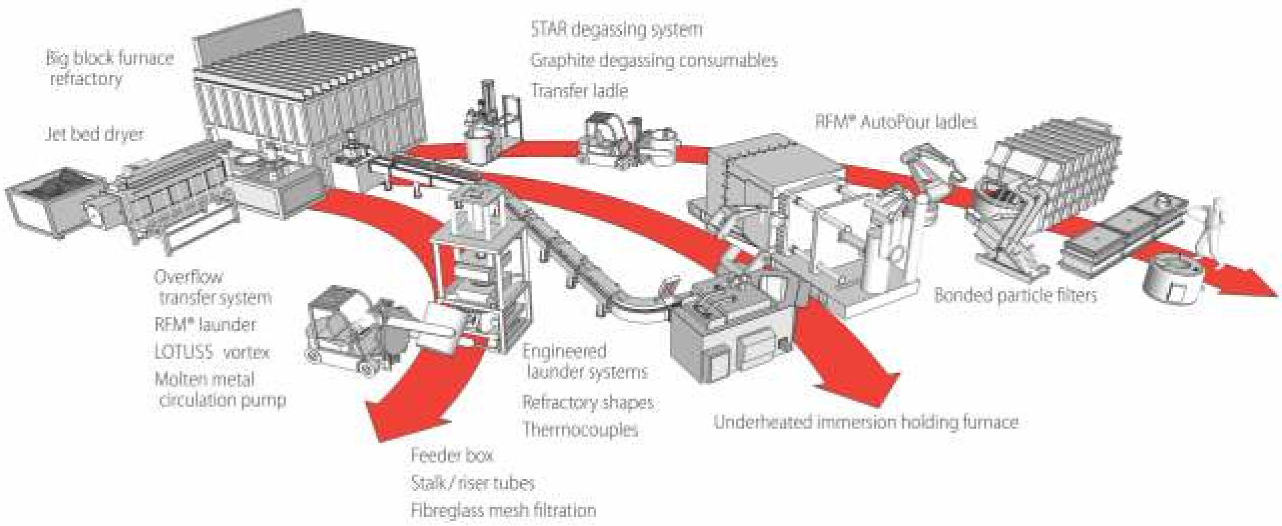
ALUMINIUM GDC TECH GREAT DIE CASTING

GREAT DIECASTING TECHNOLOGY FORUM

JOURNAL FOR ALUMINIUM CASTING TECHNOLOGY

Volume 47 - August 2021

Demand Better Cs



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Volume 47 - August 2021

ALUMINIUM GDC TECH GREAT DIE CASTING

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Note: Some images in some articles may not be clear. Interested readers may contact the author

CONSUMABLES FOR HPDC PROCESS

Continued from June 2021 issue

Die Coatings:
Types and purpose of Die Coatings:

Die face lubricant: Purpose:

(i) Protects the die from chemical attack. When molten Aluminium impinges on a steel die, the die is chemically attacked as per the reaction.

$$Fe + 3Al = FeAl_3$$

$FeAl_3$ once formed goes on building up on the die. As a result, a silvery white deposit, often referred to as 'soldering' or 'welding' appears on the die. Removal of the deposit is troublesome and often results in die damage. The die coating forms a protective layer on the die that prevents the soldering.

(ii) Protects the die from mechanical erosion. The protective layer formed by the die face lubricant is sufficiently strong to withstand the erosion of the die by the incoming metal.

(iii) Facilitates easy casting release. The die coating forms a lubricating film on the die and on the ejector pins to facilitate an easy release of the casting from the die.

(iv) Provides smooth casting finish.

(v) Provides additional cooling in hot spot areas.

(vi) Facilitates an easy flow of metal over the die face.

(a) **Piston Lubricant**

Piston lubrication is required to reduce the wear of the piston and the short sleeve.

Requirements of Die Coatings

To do the above-mentioned jobs, the die lubricants must meet the following requirements

(i) The die coating should be economical in use and capable of forming a strong lubricating film to protect the die from physical and chemical attacks by the impinging metal.

(ii) The die coating must be easily and rapidly applied to ensure fast production rates.

(iii) The die coating should not be dirty and should not produce excessive smoke, flame, obnoxious smell, and castings with blows and stains.

(iv) The die coating should spread easily and cover all the areas of the die. It should penetrate sufficiently to prevent seizure of the ejector pins and other moving parts of the die block.

(v) The die coating should not build up on the die face or the mating faces of the two halves of the die block.

(vi) The die coating should release all gases before the metal enters the die cavity, otherwise pores in the casting are produced.

Formulation of Die Coatings

(a) Die face lubricants: To achieve the above the stringent requirements, die face lubricants are formulated with a variety of raw materials that can be classified into

I. Carriers,

II. Film formers,

III. Special additives

IV. Fillers or pigments.

In the last few years, water based die face lubricants have gained a lot of favour, the world over, over the oil based coatings. The main consideration s in favour of water based coatings have been environmental and economic coupled with the improved casting quality and production rates

(b) Piston/Plunger lubricants: Graphite is a key functional material in many plunger lubricants. It can be supplied in a variety of carriers including oil, water and waxes. The carrier serves not only as a lubricant itself, but also to help distribute the additives over the surface of the shot sleeve, and, depending on the method of application, to hold the additives in place once applied. In last few years, water based plunger lubes that are compatible with automatic lubrication systems used in modern machines have been developed. Also, solid pallet form plunger coatings are also available. Excessive usage of plunger coating can lead to discoloration of castings. So, due application rates need to be established.

Conclusion:

- Appropriate selection and use of consumables in a High Pressure Die Casting Foundry can lead to improved quality and reduced end to end costs
- Knowledge of various options in available consumables and their application best practice is the key to improvement
- Newer technology and eco-friendly options improve the results of processes, their consistency, casting soundness and end to end economy .

References:

Simon R and Careil P Granular and powder fluxes for aluminium alloys, cleaning efficiency, cost and environmental aspects Foseco Foundry Practice 247

The use of granular flux to improve the quality of High Pressure Die castings: Roger S Kendrick, European Technology Manager Non -ferrous Foundries Foseco Europe, , ALUCAST 2011

Simon R.:Melt treatment of aluminum and aluminum alloy by MTS;
Foseco Foundry Practice 232

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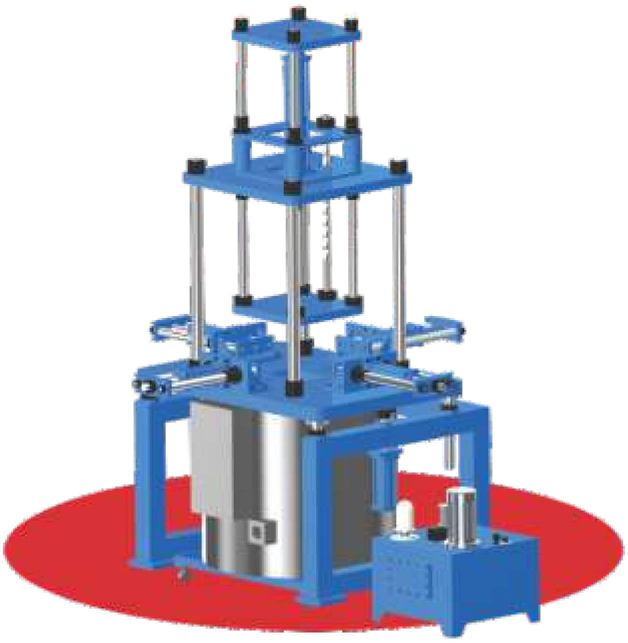

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GDC TECH GREAT DIE CASTING

Great Diecasting Technology Forum

Training Programme Calendar 2021-2022

April

Die Design
21 - 22 PDC
(Thu-Fri)
6 hrs two consecutive days

Core Technology
28 - 29 GDC
(Wed - Thu)
1/2 Day each

April 2021

May

Die Coatings
13 GDC
(Thu) - Half Day

Quality & Process Control
27 - 28 Common
(Thu-Fri)
4 hrs. Two Consecutive Day

May 2021

June

Methoding of Aluminium Gravity Die Casting
17 - 18 GDC
(Thu-Fri)

IMPORTANCE OF RELEASE AGENTS IN ALUMINIUM HPDC PROCESS
28 PDC
(Mon) - 1.5 Hour

June 2021

July

Three days programmes for begineers/buyers (at two centres)

Common

July 2021

August

Defect Analysis & Remedial Measures
6 (Fri) PDC

August 2021

September

Melting & Metal Treatment & Defect Analysis & Remedial Measures
16 - 17 GDC
(Thu-Fri)

September 2021

October

GDCTECH 2021

Virtual Conference & Exhibition
5 - 6
(Tue-Wed)

October 2021

November

November 2021

December

GDCTECH Special

Thermal Management
16 - 17
(Thu-Fri)

December 2021

January

Two Weeks Proficiency Development Programme
17 - 29
(Mon-Sat)
Common

January 2022

February

Machine Maintenance
17 - 18
(Thu-Fri)
PDC

February 2022

March

Reserve Your Dates

Programmes are Virtual or Physical
Will be conmmunicated well in advance as the situation may be
*** Programmes subject to change**

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Design and Process-Specific Optimization of Complex 3d Temperature Control Systems in Order to Increase the Effectiveness of a Combination with a High-Speed Casting Cell

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MAGMA GmbH, Germany

Continued from June 2021 issue

A systematic approach to the use of casting process simulation can be divided into the following steps:

- Definition of the goals
- Definition of the relevant variables: These can be process parameters as well as geometry variations of the component or tool.
- Selection of resilient quality or measurement criteria: Which simulation results describe the objectives or document a desired change.
- Definition of the start sequence: Number of simulations that provide statistically validated findings.
- Target-oriented evaluation of the statistical simulation data

For the virtual assessment of the Frech high-speed casting cell, all relevant geometric modifications of the casting system, the mold temperature control as well as critical process parameters were considered as variables. Specifically, the original state and the tool and process modifications planned for the second optimization step were integrated into the simulation model. For example, the resource-efficient redesign of the casting run with regard to a reduced return flow portion, reduced energy input and accelerated solidification (Figure5 a. /b.) as well as a geometric variation of the gate section to the component with regard to a fast and uniform filling of all four cavities with the lowest possible filling time differences (Figure 6 c. /d.).

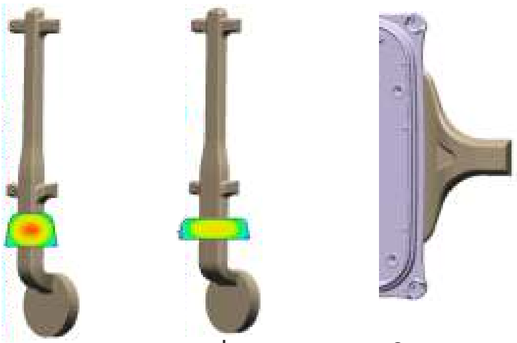


Figure 5: Geometric variants of the casting run (a. conventional / b. modified) and the gate design (c. original design / d. modified design)

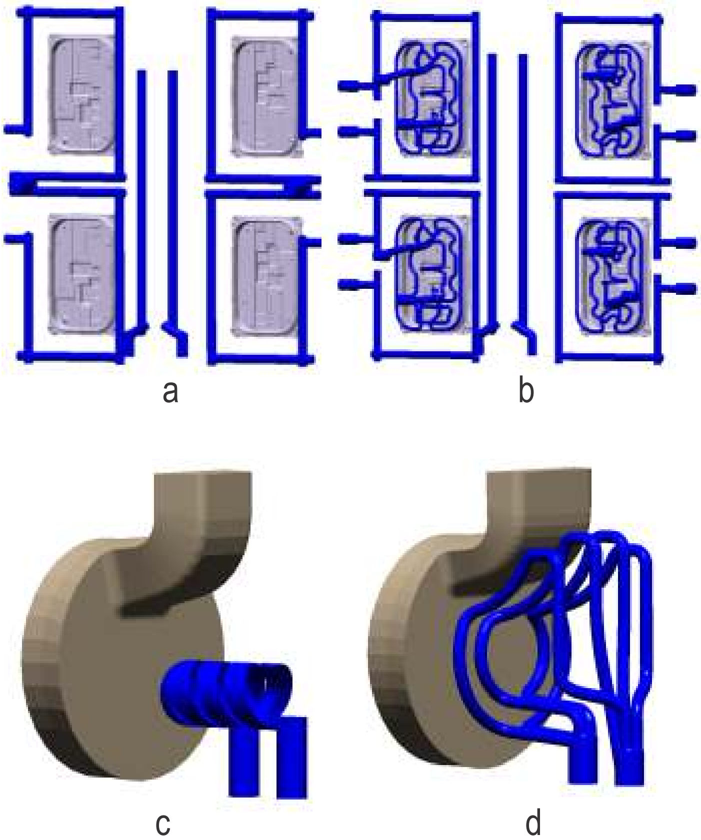


Figure 6: Geometric variants of insert temperature control (a. conventional / b. close contour) and anvil cooling ©. conventional / close contour)

In order to achieve a balanced energy balance in connection with the planned Micro Spray Technology, the conversion of the internal tool cooling (from conventional cooling channels to complex near-contour cooling structures) was also integrated into the virtual process model.

To evaluate the effectiveness and sensitivity of the different cooling variants, the following process parameters for the temperature control channels were also varied:

- Flow rate between 8 and 15 l/min
- Temperature of the cooling medium between 80 and 150 °C

Particularly in the case of complex cooling channel geometries, such as the near-contour cooling systems shown above, knowledge of the cooling or temperature control performance that can be achieved locally in the mold is of decisive importance. In MAGMASOFT® the flow conditions in the cooling channel can be calculated in parallel to the classical mold filling and solidification simulation of the cavity. Using a simple tower cooling as an example, some results of a flow calculation in the cooling channel are shown. Besides the absolute flow velocity with vectors (Figure 7 left) or pressure curves in the temperature control circuit (Figure 7 middle), the local heat transfer coefficients (Figure 7 right) of each activated cooling channel can be calculated, visualized and evaluated.

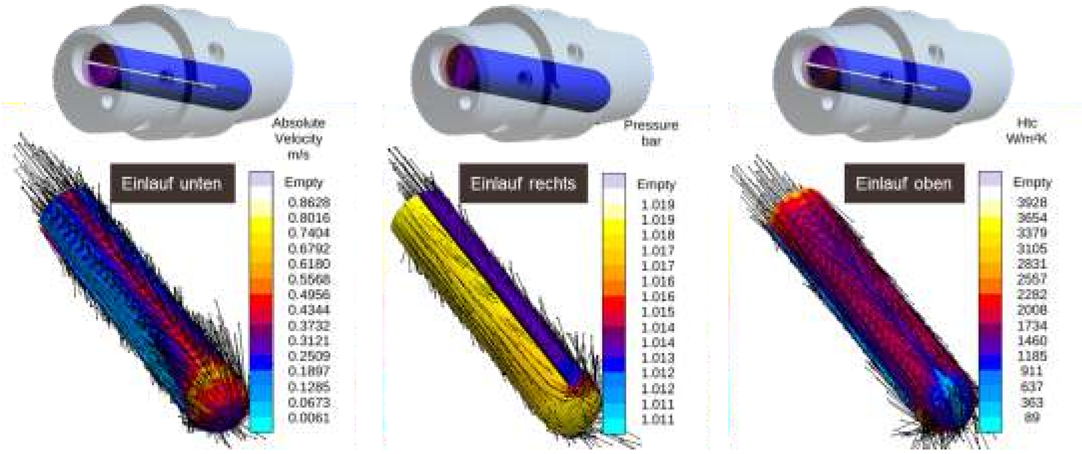


Figure 7: Exemplary presentation of the results of a flow calculation in a tower cooling system with different inflow conditions

The conventional, water-based application of release agent or the innovative WOLLIN Micro Spray Technology is taken into account in the simulation model in a simplified way by means of defined spray areas with different intensities of heat extraction from the tool surface.

In order to better evaluate the robustness of the technical casting design, the switchover time was integrated into the virtual investigation as a further process variable - from the slow first to the fast second phase with the states early, medium, late (Figure 8)

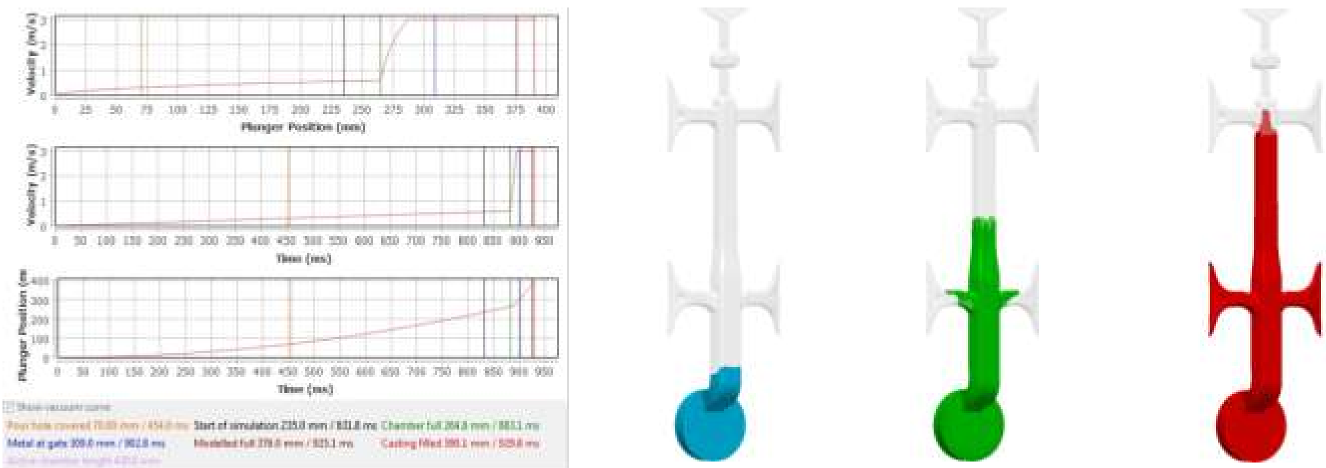
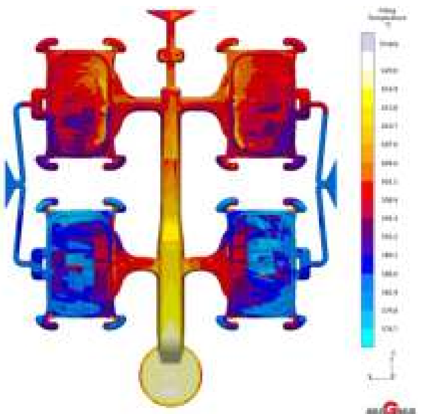


Figure 8: schematic shot profile and visualization of the varied switchover point (early/medium/late)

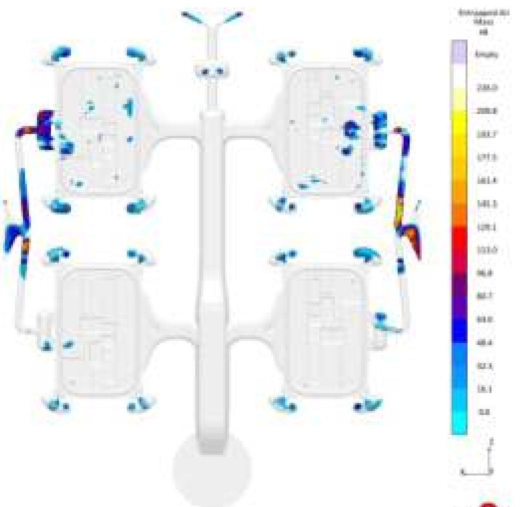
The most important step in the systematic and goal-oriented use of casting process simulation is the definition of meaningful quality criteria and measurement variables for the evaluation of the virtually examined process variants. For the heat sink, the selection of the relevant MAGMASOFT® results is based on the defined requirements of the component:

- Flow error - Minimum fill temperature (cold run risk) in the 4 cavities
- Surface defects – Mold Erosion (washout) and Die Soldering (adhesion/sticking)
- Fill time differences - Fill Time as maximum difference between all cavities
- Internal defects - Entrapped Air Mass (gas porosity) and Porosity (shrinkage porosity)

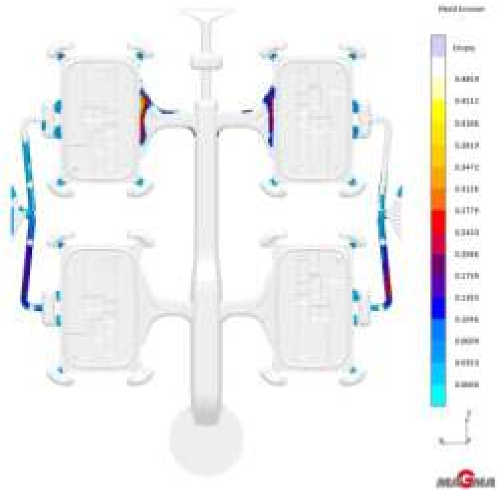
In the following, some corresponding 3D results from casting process simulation with MAGMASOFT® are shown as examples for the above-mentioned quality criteria (Figure 9).



a



b



c

Figure 9: classic 3D MAGMASOFT® results for the evaluation of flow defects (Fill Temperature), imperfections in the part or porosity (Entrapped Air Mass) or surface defects on the part and tool (Mold Erosion)

The number of defined variables and their degrees of freedom determine the experimental space for the virtual experiments:

- Casting run design conventional / optimized (2)
- Gate geometry narrow / wide (2)
- Anvil cooling conventional / close contour (2)
- Insert cooling conventional / close contour (2)
- Flow rate 8 / 15 l/min (2)
- Medium temperature 80 / 150 °C (2)
- Spraying process conventional / micro spraying (2)
- Changeover point early / medium / late (3)

In order to reduce the calculation effort, AGMASOFT® allows using different statistical design strategies (e.g. Sobol) to generate the so-called start sequence. Usually, the approach is "statistically validated findings with a minimum number of experiments". Within the benchmark project "High Speed Casting Cell" a full factorial DoE (Design of Experiments) was used, i.e. all 384 theoretically possible parameter combinations were simulated. The virtual experiment No. 108 corresponds to the initial process after the conversion of the original series process to the "High Speed Casting Cell".

Since a conventional evaluation of the virtual experiments using 3D results is not feasible, the simulation results in MAGMASOFT® are additionally automatically converted into quantitative numerical values according to defined criteria. With the integrated statistical analysis tools, all investigated experiments can be evaluated comfortably, clearly and quickly.

The selected quantitative criteria for casting quality, die loading or the efficiency and robustness of the manufacturing process were summarized into easy-to-understand key Performance indicators (KPI's) via so-called User Results. The KPI's are based on the real production-related KPI OEE, which is also gradually being adopted in die casting. As a measure of the increase in effectiveness, OEE combines the categories availability (e.g. tool life,), speed (e.g. cycle time,) and quality (or scrap), (Figure 10).

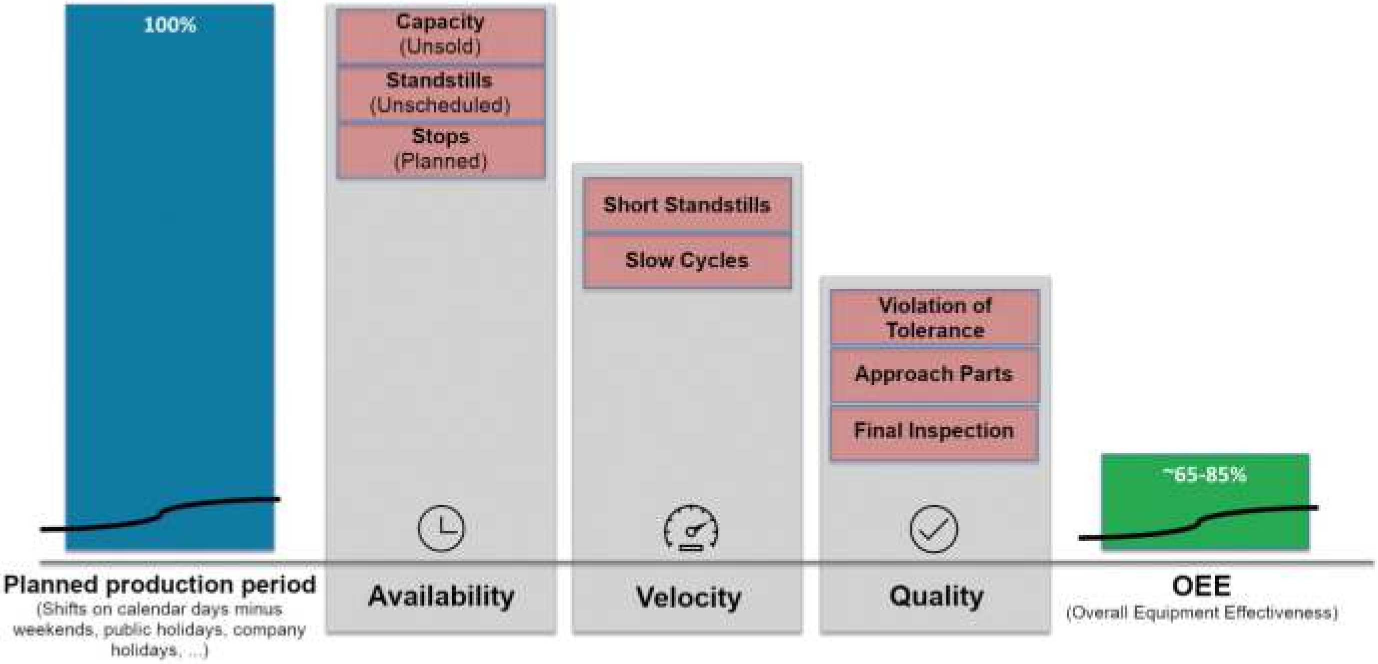


Figure 10: Composition of the production key figure OEE (Overall Equipment Effectiveness) from machine availability, process speed and the resulting component quality

The formation of the key figures for the description of an "optimal process" - i.e. the best compromise between product quality, economic efficiency and robustness of the manufacturing process - is achieved by mathematically linking the MAGMASOFT® results. The virtual key figures do not necessarily correspond to physical relationships and were standardized to reference experiment no. 108 for a simplified evaluation of the complex virtual test field. Values greater than 1 correspond to an improvement over the initial state of the "high-speed casting cell". The reduction of the cycle time is given as a percentage in reference to the original series process.

Cycle time	Filling time + time to die opening (solidification time during the run) + defined idle times, e.g. for spraying/blowing
Casting quality	Minimum filling temperature (cold run risk) / trapped air mass in the components * Porosity risk
Productivity	Ratio component / shot weight * difference in filling time between the upper and lower nests
Tool load	Risk of shape erosion + risk of sticking

In MAGMASOFT®, a ranking of the virtual experiments is generated on the basis of the normalized ratios (Figure 11), which, with uniform weighting of the ratios, allows an immediate determination of an optimal solution.

Rank	Design	Cycle Time	Cycle Time Reduction	Casting Quality	Productivity / Robustness	Tool Life
Rank 1	Design 316	24.7	0.65	1.09	2.14	3.59
Rank 2	Design 315	24.91	0.656	1.08	2.14	3.56
Rank 3	Design 314	25.69	0.676	1.08	2.14	3.47
Rank 4	Design 313	26.05	0.685	1.08	2.14	3.45
Rank 5	Design 220	24.68	0.65	1.25	2.13	2.33

Figure 11: Top 5 virtual experiments from the MAGMASOFT® ranking with uniform weighting of key figures

In order to take the real process conditions into account, the virtual experimental design was evaluated in detail and interactively with the aid of the parallel coordinate diagram (Figure 12). The columns (from right to left) show the variables with the respective states and the defined key figures. The scaling is based on the cycle time reduction. Each line in the diagram corresponds to a virtual experiment. The sliders allow a quick adjustment of the desired boundary conditions and objectives. (Figure 13) shows an individual selection based on the primary optimization goals for the "High Speed Casting Cell". The virtual experiment no. 274 is the chosen compromise between product quality, economic efficiency and robustness of production while reducing the cycle time by almost 35% compared to the original series production.

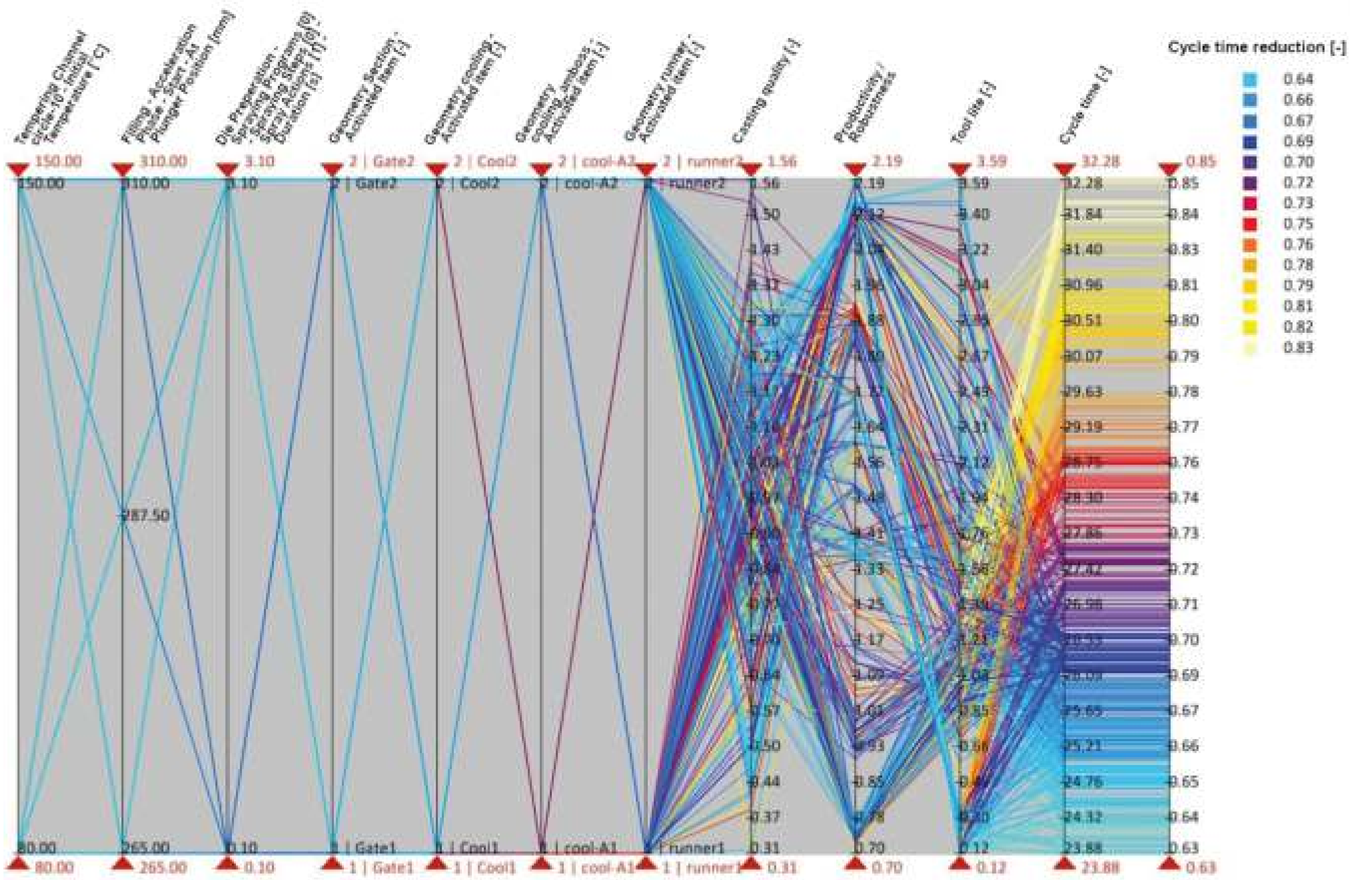


Figure 12: Interactive analysis and evaluation of the virtual test space using the parallel coordinate diagram; each line describes a simulation with the corresponding combination of variables and the resulting quantitative results or key figures

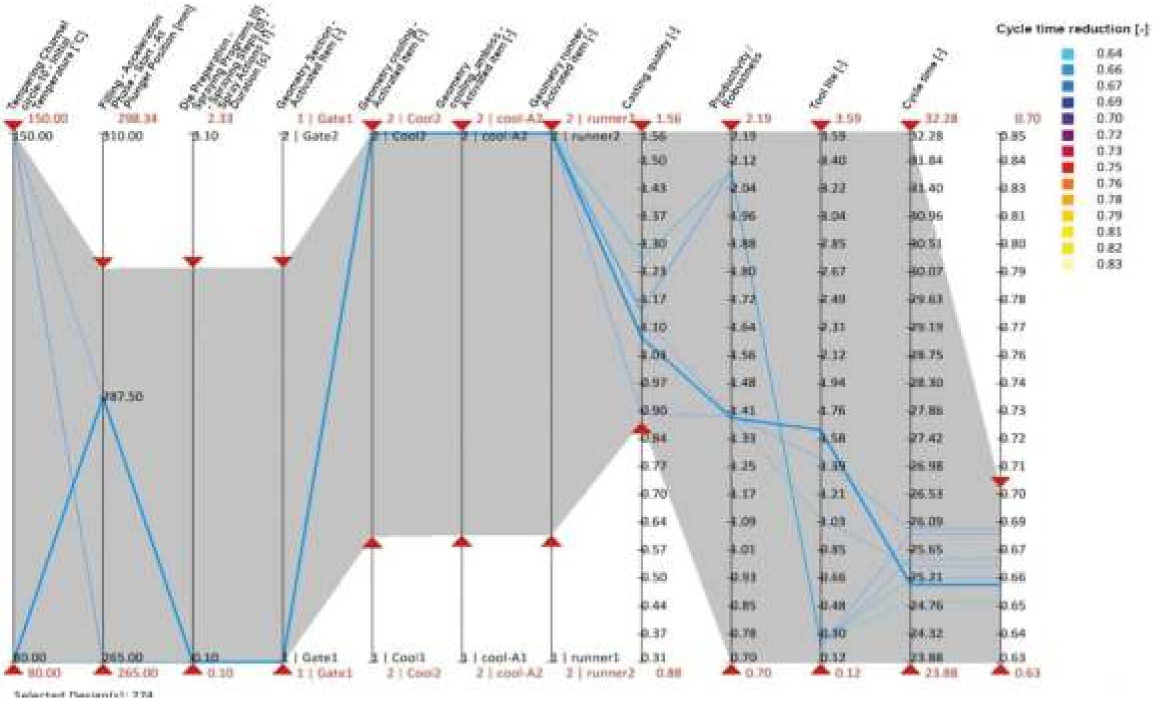
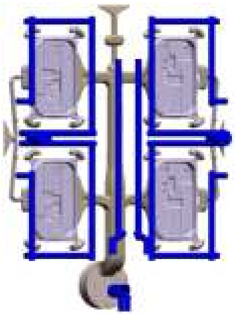


Figure 13: Individual selection of the "optimum process" taking into account the specific plants and process conditions; experiment no. 274

Rank	Design	Cycle Time	Cycle Time Reduction	Casting Quality	Productivity / Robustness	Tool Life
Rank 67	Design 228	24.95	0.657	1.01	1.53	1.48
Rank 68	Design 88	24.56	0.646	0.974	1.36	1.64
Rank 69	Design 299	27.73	0.73	1.31	1.89	2.1
Rank 70	Design 276	23.99	0.631	0.972	1.39	1.1
Rank 71	Design 300	27.5	0.724	1.37	1.88	1.74
Rank 72	Design 270	25.5	0.671	1.15	2.09	0.219
Rank 73	Design 103	28.36	0.746	0.9	2.13	3.16
Rank 74	Design 39	25.78	0.678	1.08	1.84	1.2
Rank 75	Design 3	27.66	0.728	0.885	2.11	2.64
Rank 76	Design 274	25.11	0.661	1.08	1.39	1.64
Rank 77	Design 324	24.98	0.657	0.638	1.88	1.61
Rank 78	Design 179	24.33	0.64	0.49	1.63	2.01
Rank 79	Design 104	28.46	0.749	0.897	2.13	3.15
Rank 80	Design 80	24.33	0.64	0.76	2.08	0.215

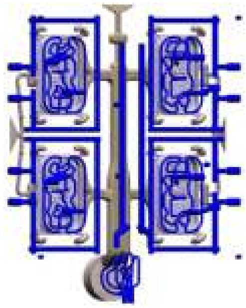
Figure 14: The virtual experiment no. 274 determined from the individual evaluation is on position 76 in the MAGMASOFT® ranking with uniform weighting of the key figures

After the modification of the die casting tool at Oskar Frech GmbH & Co. KG, the process was implemented using the virtually determined parameter combination in the "high-speed casting cell". In combination with the use of Micro Spray Technology, the close contour temperature control integrated into the tool allows a reduction of the total cycle time to approx. 23 seconds (Table 2). This corresponds to a capacity increase of almost 40% compared to the original series process.



Cooling: conventional
Anvil: conventional
pouring run: conventional
Bleed: narrow
Flow rate: 15l/min
Temp. medium: 150 °C
Spraying: conventional

Virtual Design 118



Cooling: close contour
Anvil: close contour
Casting run: optimized
Bleed: wide
Flow rate: 15l/min
Temp. Medium: 80 °C
Spraying: Micro Spray
Switchover point: medium

Virtual Design 274

High Speed Casting Cell K640		K640 including tool modification	
	[sec.]	[sec.]	
Closing	2,7	2,7	
Metering	2,1	2,1	
Casting			
1. Phase	1,2	1,2	
2. Phase	0,1	0,1	
Cooling Period	6	**5,1**	Reduction through WZ – temperature control
Opening	2	2	
Ejector before	0,4	0,4	
Withdrawal	4,9	4,9	
Spraying	11,5	4,5	Micro spraying in combinatio with WZ - temperature contro
Ejector back 0,5 sec			During spraying
Casting plunger 1,5 sec			During spraying
Waiting time for removal until sprayin starts	2,5	2,5	Optimized process
Total cycle time	33,4	**23**	**Reduction of the cycle time a further 31%**

Table 2: Comparison of the process times for the high-speed casting cell with series tool and with the modified tool and use of Micro Spray Technology; cycle time reduction by almost 40% to 23 seconds

Intelligent temperature control of die casting tools to increase OEE

"The temperature control of die-casting tools comes last" - This is the principle according to which the positions and dimensions of temperature control channels are generally designed today. If no information is available at this time about the heat balance of the die during operation, there is no other way. However, this approach is by no means up to date. The potentials of front loading, which has been known in mechanical engineering for 140 years, the possibilities of computer-aided optimized design of casting processes, which have been available for 30 years, and the modern, partly generative manufacturing technologies for contour-near and contour-adapted temperature-controlled tool segments are not used. The above-mentioned potentials are known and quantifiable - in individual cases, the only thing that is required is a decision for a different approach.

The approach proposed in this paper allows not only the identification of the concrete manufacturing technology solution for the tool and the casting process, but also the determination of the best compromise that the caster strives for in terms of quality and economy. Almost free of economic or productive risks, any scenarios can be examined for their contribution to increasing the efficiency (OEE) of a die casting cell. The methodical approach allows correlations between production parameters and quality features of the casting to be generated systematically and early in the development process, even for complex issues.

Decisions are backed up on the basis of a CAE development process in which the component and process are simultaneously optimized by the designer and the foundry man, thus supporting the product developer, the toolmaker and the foundry expert in designing robust, cost and resource-efficient products and processes.

Dr. W. Sokolowski, R. Aspacher, N. Clauss, Oskar Frech GmbH+Co. KG, Schorndorf, Germany

Dr.-Ing. G. Hartmann, Dipl.-Ing. H. Rockmann, Dr.-Ing H. Bramann, MAGMA GmbH. Aachen, Germany

Captions

Figure 1: "Thermally nimble" die with close contour and contour-following temperature control, consisting of temperature control channel meanders and copper pins for the connection between temperature control medium and cavity (Contura MTC: Plastics + Processing 40/2019 Kuhn Fachverlag, page 65 Citation of Contour article)
Figure 2: 4-fold series tool for the die-cast aluminum heat sink; the tool inserts and anvil have conventional cooling channels and stab cooling
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Table 2: Comparison of the process times for the high-speed casting cell with series tool and with the modified tool and use of Micro Spray Technology; cycle time reduction by almost 40% to 23 seconds

Concluded...

REPORT ON VIRTUAL CONFERENCE ON RECYCLING OF ALUMINIUM FOR ALLOY MANUFACTURING & EXTRUSION BILLET CASTING

Arkey Conference & Engineering Services organised VIRTUAL CONFERENCE ON RECYCLING OF ALUMINIUM FOR ALLOY MANUFACTURING & EXTRUSION BILLET CASTING - Date 8-9 July 2021. Keynote Address delivered by Dr. Anupam Agnihotri, Director, JAWAHARLAL NEHRU ALUMINIUM RESEARCH DEVELOPMENT AND DESIGN CENTRE (JNARDC) on **Overview of the Aluminium Recycling and Alloy Manufacturing**

Guest Of Honor was Sanjay Mehta, President, MATERIAL RECYCLING ASSOCIATION OF INDIA and delivered a talk on **Overview Of The Scrap Market Recycling And Environmental Aspects**

Mr. Anil S. Kulkarni, CMD, Pooja Castings Pvt. Ltd., Vice President GDCTECH Forum, was the Valedictory Chief Guest
Following were the presentations & Speakers

- **Scrap Identification, Segregation And Processing**
  Srinivas Rao, Consultant
- **Briquetting Optimises Recycling Aluminium Chips / Swarf**
  Ms. Romy Wadhwani & Sunil Makhijani, H.T. Makhijani & Associates
- **Scrap Standardisation Keeping View - India**
  Vikram Jhunjhunwala, Director, CENTURY NF CASTINGS
- **Chips And UBC Treatment Technology**
  Dhananjay Navangul, Managing Director, DHANAPRAKASH INDUSTRIAL CORP.
- **Efficient Scrap Melting**
  Girish S. Vispute, Head-Development, FURNTECK ENGINEERS PVT. LTD.
- **Selecting The Right Refractory For Furnaces & Application**
  Timothy L Hoyt, Manager Product Services Engineering, Allied Mineral Products LLC, Columbus, Ohio, USA
- **Application of Pump & Vortex System in Aluminium Recycling .**
  Anil Keswani , Regional Manager South Asia , Pyrotek Netherlands B.V.
- **Furnaces & Billet Casting Metal Preparation**
  Sunil Atrawalkar, BE Metallurgy, Proprietor – Metal Technologies India
- **Special Alloys Applications (Defence/Railway)**
  N. S. Parulekar, Marketing Consultant, SOHAM SOURCING
- **Alloy Ingot Manufacturing & Metallurgy**
  Srinivas Rao, Consultant
- **Savings & Efficiency Improvement Through Fluxing Techniques**
  Shrikant A. Bhat, Head Non-Ferrous Foundry, FOSECO INDIA LIMITED
- **Effect Of Alloying Elements & Homgenising**
  Sunil Atrawalkar, BE Metallurgy, Proprietor – Metal Technologies India
- **Digitisation Of Aluminium Smelting Process**
  Bhushan Bhatt, Partner – VEZAPP SOLUTIONS LLP

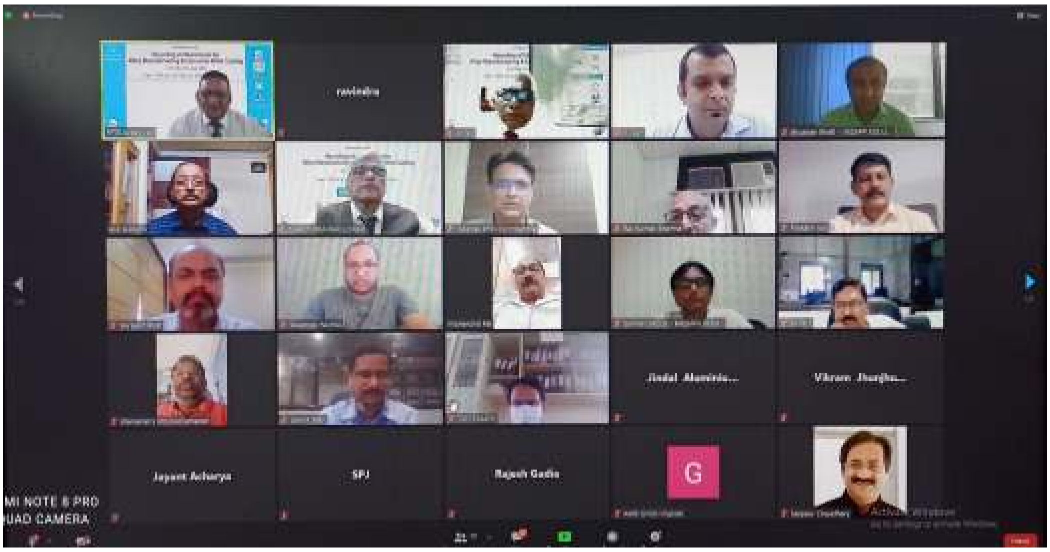
Total 44 Delegates Attended the Programme.

Conference was supported by

1. Aluminium Extruders' Council (ALEX)
2. Great Diecasting Technology Forum (GDCTECH forum)
3. ASMA
4. MRAI
5. MTLEX

Mr. R. T. Kulkarni, on behalf of Arkey & Sponsoring Organisation, proposed vote of thanks to all Chief Guest,speakers and all participants and assured to meet next year again.

Glimpses of the Conference Delegates



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GREAT DIECASTING TECHNOLOGY FORUM

"METHODING OF ALUMINIUM GRAVITY DIE CASTINGS"

Date : 17th June 2021

Faculty : Ravi Agarwal, CE (T), Pooja Castings Pvt. Ltd.,

Number of Participants: 37 nos. from following companies

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- ALPHATEK TOOLING
- ALTECH ALLOYS INDIA PVT. LTD.
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- AURANGABAD ELECTRICALS LTD.
- BEST CAST IT LTD.
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- UNITED METALLURGICALS PVT. LTD.
- VEE J PEE ALUMINIUM FOUNDRY PVT. LTD.
- THE AUTOMOTIVE RESEARCH ASSOCIATION OF INDIA
- SAMKRG PISTONS & RINGS LIMITED
- SUNDARAM CLAYTON LIMITED

"IMPORTANCE OF RELEASE AGENT IN ALUMINIUM HPDC PROCESS"

Date : 28th June 2021

Faculty : Madhav Athavale, Consultant

Number of Participants: 35 nos. from following companies

- 3M INDIA LTD.
- AAKAR FOUNDRY PVT. LTD.
- AURANGABAD ELECTRICALS LTD. (AEL)
- CAPARO ENGINEERING INDIA LTD.
- CERAFLUX INDIA PVT LTD.
- COOPER CORPORATION PVT. LTD.
- GODREJ & BOYCE MFG. CO. LTD.
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A STORY OF QUALITY

Pramod Gajare - Consultant, Email: pramodgajare2013@gmail.com

It was a sunny day in April this year. My daughter received a parcel from a famous e-commerce company. On opening it, she was unhappy. "This shade of blue was never expected. The texture is also not good. I am going to return this pair of jeans" she said to herself. I was observing it silently.

Soon I returned to continue reading the newspaper. On the next page the news attracted by attention.

*An Auto maker in India announced a **recall** of 77,954 units of some select models in India over a faulty fuel pump.*

The fuel pumps installed in these vehicles may contain defective impellers, which could, over time result in the engine stopping or not starting.

*These77,954 cars, which were manufactured between 2019 and 2020 have been **recalled** as a part of preventive **recall**.*

I started thinking. Although it looks normal; my daughter's reaction for the pair of jeans and this news about recall, both have a very strong relationship. These show changing faces of customer expectations about product quality.

For the denim the manufacturer may not be able to know the exact reason for which the girl refused to accept the product. On the other hand, in the recall the car owner may not be knowing that there is a possibility of any malfunction in his car. The manufacturer is recalling his car to protect his customer from possible mishap.

What is Quality?

There are many definitions available for the term "Quality". Let us not confuse ourselves with those complicated words and phrases used in these definitions.

Quality in business, engineering and manufacturing has a practical interpretation as the ***non-inferiority*** or ***superiority*** of something.

Quality is a perceptual, conditional, and somewhat subjective attribute. It may be understood differently by different people. Everybody looks at Quality from his/her point of view.

The person looks at Quality with reference to his/her

- status or position
- responsibility and authority
- Working conditions etc.

This can be easily understood through an example of cylinder head casting. It will be interesting to see how different people perceive about quality of cylinder head.

A Foundry owner producing cylinder head casting will focus on conformance of various features like dimensions, metallurgical aspects and other specifications. He will also concentrate on quantitative conformance. He will look for the degree to which the castings were produced correctly. He will measure quality in terms of In-house rejection PPM and customer return PPM.

Service person at the Service center for the car will measure quality in terms of reliability. His attention will be on the degree to which that a product is reliable. He will relate it to the number of cases of problems reported for the cylinder head. He will also try to do comparison of different model of cars for problems reported for the cylinder head.

The case of car owner will be totally different. It is likely that the car owner may not be even aware that there is a part called cylinder head in his car. But still some of his

Quality expectations are related to the cylinder head. The car owner will look for the engine performance in terms of pick-up, Fuel consumption, maintenance etc. His overall expectations of Flawless driving will aim on Noise, Vibration and Harshness (NVH conditions, as these are recognized in auto industry).

If someone wants to simplify, meaning of quality is fitness for purpose.

The word "purpose" can be further expanded as:

- fitment,
- function,
- performance,
- life,
- environment friendly,
- safety for user,
- Safety for society etc.

At the onset it is thought-provoking to know, how the concept of quality is evolved. Going through the pages of history, reveals an interesting story.

Evolution of Quality

In initial days when industrialization just started, the concept of Quality was practically not there. Whatever was produced was being dispatched to the customer. So, the activities of checking, inspection or control were totally absent.

As time passed, the customer started sending back the bad parts to the producer. The producers realized that they had to calm down the customers somehow; may be by repairing the product or paying back some discount etc.

This situation led to introduction of inspection. Inspection of all the products started and only those products, which pass through inspection, were dispatched. Slowly a heap of rejected material was accumulated in the shop. The producers were unaware of what could be done of the rejected products. At this time, still there were complaints from field but in less numbers. The inspector who sorted out good and bad products was being fired for wrong inspection without asking to the operator/supervisor who produced rejected pieces.

The next phase was of a post-mortem stage. Whenever a piece got rejected, analysis was done as to why it was produced as rejection and corrective action was tried. Different logics were added for quite some time and ultimately concept of Quality Control landed. Two major points were realized at this time.

1) 100% inspection is not fool-proof.
2) Rejection can not be stopped, unless preventive actions are thought of.

This realization gave rise to concept of Quality Assurance against Quality Control concept. Many new tools like control charts, sampling plan, setting approval, cause and effect diagram were added in due course of time. At this stage the results targeted at 1% defects were thought of as best and up to 3% defects was an acceptable quality level.

Subsequently, because of high rate of production and consumption, concept of full satisfaction of customer started rising. Thinking of Zero Defect started. The concept of FMEA (Failure Mode and Effect Analysis) and concept of process capability were two major activities to reach zero defect targets.

Instead of hand over of a machine for production, handover of the process with required process capability index started. Role of operator and suppliers were also realized. Long term preventive actions were started with involvement of personnel from Design and Process Engineering. At the later stage MSA (Measurement System Analysis) was added. Training and active participation of the employees (particularly of operators) came in picture. This led to TOTAL QUALITY CONTROL concept.

In 1987, ISO-9000 standard was introduced. This standard brought understanding of classes of customers and expectations of each class of customer regarding Quality. This strengthened the activity of Quality Function Deployment. This stage was identified as a reliability stage.

From example of one GDC foundry this relationship can be understood clearly. This foundry is producing Pump Body casting for a passenger car. The customers identified are as follows:

- Pump manufacturer.
- Vehicle manufacturer.
- Vehicle owners.
- Garages serving these vehicles.
- Mechanics serving these vehicles.
- Shopkeeper selling spares for these vehicles.
- Drivers of the vehicles.
- Passengers sitting in these vehicles.
- Society.
- Species affected by the environment. (Human being, birds, animals, trees etc.)

Similar to this the concept of internal supplier-customer relationship came in existence. A person performing one operation is internal supplier of person performing next operation. A person performing next operation is an internal customer for the person performing previous operation. Similarly, this is applicable for the concerned sections or departments also.

Let us see this relationship through example of above foundry. This foundry is supplying machined and painted castings of Pump body. Typical process flow in this foundry is like this; Receipt of ingots → Inspection of ingots → Storage of ingots → Melting → Metal transfer → Die casting → Gate cutting → Fettling → Shot blasting → Painting → Machining → Final inspection Packing and Dispatch.

Some of the internal supplier-customer relationships in this foundry will be as follows:

- Packing and dispatch person is internal customer of final inspection person.
- Machine shop is internal supplier of Final inspection section.
- Paint shop is internal supplier of Machine shop.
- In paint shop, the pre-treatment operator is internal supplier of the painter.
- Paint shop is internal customer of Fettling section.
- Fettling section is internal customer of Gate cutting section.
- Die casting shop is internal supplier of Gate cutting section.
- Metal transfer operator is internal supplier of Die casting shop.
- Metal transfer operator is internal customer of the Melting operator.
- Stores Department is internal supplier of Melting shop.
- Receiving Stores section and Receiving Inspection section are internal supplier as well as internal customer of each other.

The rejection or defects were earlier measured in terms of percentage of the parts produced i.e. in terms of % rejection or % defects. Use of new measuring scale PPM (parts per million) started. This mean number of defective parts in one million parts produced.

In last 10 years the meaning of PPM changed dramatically. By and large, up till now, PPM was understood as defective parts per million per operation. Now in the new context, it will mean that defective parts per million for all operations - within and outside of factory i.e. all operations in factory, assembly and testing at vehicle manufacturers place and use/ abuse by vehicle owner/ driver etc.

In 1994 the QS 9000 standard was introduced for automotive industry based on ISO 9000 standard. Subsequently it was superseded by the standard TS 16949: 1999. Further it is transformed in IAFT 16949:2016 This standard is called as “Technical specifications for the suppliers of Automotive Industry”. This standard promotes the **adoption of process approach** and aims towards;

- ✓ Continual improvement
- ✓ Defect prevention
- ✓ Reduction in variation and waste throughout the supply chain

For achieving above, this there is a focus on use of statistical tools in this standard. Two important points are stated in this standard.

- For each process, appropriate statistical tools must be determined during APQP (Advanced Product Quality Planning). The identified statistical tools must be included in control plan.
- Everybody in the organization must

understand and make use of basic statistical concepts in their work. Few examples of these concepts are;

- Variation
- Control (stability)
- Process capability
- Over adjustment

In order to protect Consumer's interest and safety of the consumer as well as safety of the society at large, a new development took place. Whenever any complaint from the field is analysed, the severity and spread of the defect is judged in systematic manner. If the defect is of serious nature, then number of vehicles which are under suspicion for that defect is judged based on the Traceability system. The traceability system gives information about the period when the suspected parts were assembled on vehicles and number of vehicles produced in that period. The suspected vehicles are called back at the Dealer's place and these are inspected for the said defect. The defective assemblies detected during this inspection are replaced free of cost. This activity is called as Recall. This started in recent years in India; there are strict regulations and laws in advanced countries for protection and safety of consumer and society, which form binding on the vehicle manufacturer. This attracts a huge amount of penalty to be paid by the manufacturer for the damage to consumer due to faulty product. In India similar binding will come very soon through revision in current regulations and laws.

Cost of Quality

Our journey through pages of history reveals that the concept of quality evolved over time and many activities were added over a century. Since every activity has some cost; Quality has a cost.

In any business, achieving the right quality of product or service is just not sufficient. The cost of achieving the right quality must be carefully managed and monitored. This helps in long term for making the business successful and to earn reasonable profits. The cost of quality is a true measurement of the efforts taken to achieve right quality.

The Cost of Quality is a management tool which provides;

- Method to evaluate and monitor overall effectiveness of management of quality
- Means to determine problematic areas
- Means to determine action priorities

The Costs of quality is similar to cost of maintenance, production, design, sales etc. Hence it can be budgeted, monitored and analysed.

The quality costs are divided in three types namely prevention costs, appraisal costs and failure costs. The failure costs are in two parts i.e. internal failure costs and external failure costs.

Prevention costs

There relate to design, implementation and maintenance of the quality management system. Prevention costs are planned and incurred before start of production or operation. The prevention cost is further divided in the elements as below.

Cost of Quality Planning: Cost for creation of quality plans, plans for reliability, production, process control, inspection and other special plans (e.g. pre-production trials) required to achieve quality objectives.

Cost of Quality assurance: Cost for creation and maintenance of overall quality management system.
Cost of Inspection equipment: Cost for the design, development and/or purchase of equipment for use in inspection work.

Cost of Training: Cost for the development, preparation and maintenance of training programs for operators, supervisors and managers.

Miscellaneous costs: Costs for clerical activities, travel communication and other office activities.

Appraisal Costs

These are costs of evaluation. These are associated with evaluation of purchased material, processes, semi-finished and finished products etc. These costs include following elements.

Cost of verification: Costs for verification of incoming material, process set-up, first-off inspection, in-process inspection and final inspection.

Cost of Quality audits: Costs for quality audits conducted to check that the quality management system is functioning satisfactorily.

Cost of Inspection Equipment: Cost for calibration and maintenance of all equipment used for inspection.

Cost of vendor rating: Costs for evaluation and approval of vendors and monitoring quality performance of vendors.

Internal Failure Costs

These costs occur when the product or service fails to meets the specified standards, and detected before dispatch to customer. These costs include following elements.

Cost of scrap: Cost of defective products, that can not be reworked, repaired or sold.

Cost of Rework or Rectification: Costs for correction of defective material or errors to meet the requirements.

Cost of Re-inspection: Costs for re-examination of the products or work which has been rectified.

Cost of Downgrading: The product is usable but does not meet specifications and may be sold as 'second quality" at lower price.

Cost of waste: Cost of activities associated with doing unnecessary work or holding stocks as a result of error.

Cost of Failure analysis: Cost of activities required to establish the causes of internal failure of product or service.

External Failure Costs

These costs occur when the product or service fails to meets the specified standards, and detected by the customer. These costs include following elements.

Cost of Repair and servicing: Cost for doing repair or servicing of the products returned by customer and the products which are in the field.

Cost of replacement: Cost of replacing the failed products or doing re-servicing under guarantee.

Cost of Complaint handling: Costs involved for all the work related to handling of customer's complaint.

Cost of Returns: Cost of the rejected products including cost of transportation.

Cost of Failure analysis: Cost of activities required to establish the causes of failure of product or service.

Loss of goodwill: Impact on reputation and image, which has adverse effect on the future prospects of the organization.

Liability cost: These are costs of the claims due to legal responsibility. This also may include loss of business.

The target value of quality cost and its distribution in the categories of prevention, appraisal, internal failure and external failure vary from industry to industry as well as organization to organization. Cost of quality can never be zero. This is simply because the prevention costs are always to be incurred. One can reduce the failure and appraisal cost.

However, to reduce the failure and appraisal costs it is must to have Robust process controls to reduce /eliminate occurrence of nonconformity. At the same time systematic adherence to Traceability to have better damage control.

Traceability

Traceability is the series of links that exists between a part and data recorded previously during its development, manufacturing, and control processes. It includes all links necessary to identify causes of possible product variations during a well-defined time frame. A very easy example is "Engine Number punched on the engine".

Significance of Traceability

It provides immediately the data necessary to analyze and resolve problems and to isolate the defective products. Also enables appropriate, timely, and less costly action to be taken to resolve problems arising at customer end or in the market.

Traceability reduces the

- Quantity of recalled products,
- sorting of recalled products,
- or reworking of recalled products

It also helps in identification of the responsibilities in a clear and unmistakable manner.

Product Recall and Traceability

The typical Activity Flow is as follows.
Car owner faces problem → Service center → Primary verification → Car Manufacturer → Analysis → Tier one supplier → Analysis → Foundry → Analysis → Outcome (defect nature, period of production, suspected quantity) and corrective & preventive actions → Tier on supplier → Analysis → Car Manufacturer → Risk assessment → Decision about Recall → Declare Recall from the field.

Linkage of Traceability and Process at the Foundry

The typical flow is as below.
Foundry receives the complaint Analysis Outcome (defect nature, period of production, suspected quantity) and corrective & preventive actions.

To make it happen relevant important data must be identified and recorded for each step of process starting from Raw material supplier receipt in stores Packing and Dispatch.

Epilogue

As we saw the quality concepts were gradually changed from the achievement of quality standards, satisfaction of customer needs, and expectations to customer delight. Since merely satisfying customers is not enough to ensure customer loyalty, the business houses gradually focus on customers' emotional responses and their delight in order to pursue their loyalty. The emotion of "delight" is composed of "joy" and "surprise," which can be achieved as the customers' unstated requirements are satisfied. In the denim story just because you don't like the product it is replaced or the money is paid back without asking any question. In case of recall also before the customer experiences the problem, the defective part in the car is replaced.

John Ruskin had said once, "Quality is never an Accident. It is always the result of intelligent effort".

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