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GREAT DIE CASTING TECHNOLOGY FORUM

JOURNAL FOR ALUMINIUM CASTING TECHNOLOGY

Volume 48 - October 2021

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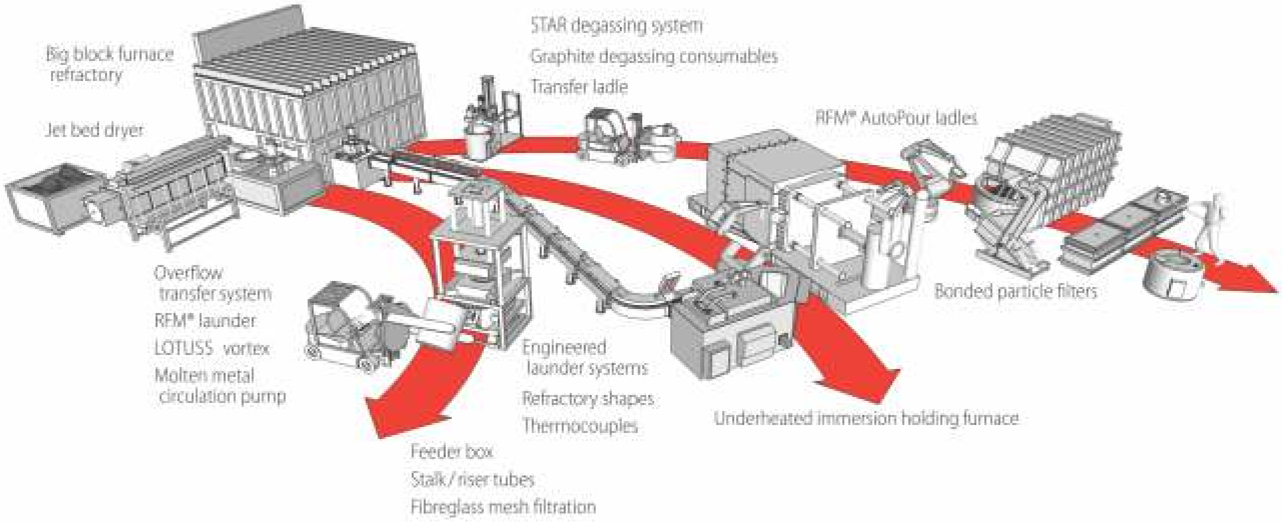

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Volume 48 - October 2021

ALUMINIUM GDC TECH GREAT DIE CASTING

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Wish You All a Very
Happy Deepawali 2021

Let this Deepawali mark the beginning of Cheerful, and Prosperous Year to come

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VESUVIUS

FOSECO

FROM THE FOSECO ARCHIVES

CARE OF CRUCIBLE IN HANDLING AND PRACTICE
TO INCREASE ITS LIFE & EFFICIENCY

In a foundry, Crucible is possibly the most important but least cared element of the melting process

Crucibles are used very satisfactorily for a number of years for the melting and holding of Aluminium and Copper alloys. No complicated precautions are necessary to achieve consistently good results from the crucible; however, FOSECO's accumulated experience with customers in many different plants over the world has demonstrated that better crucible life and good clean metal quality can be consistently obtained only if a few simple precautions are followed.

A crucible has adequate strength and toughness to take on handling and the application, for which it is intended, that is the melting and holding of metal. However, being a ceramic object, it will not stand abusive treatment such as chiseling out of dross with a heavy rod or the strain of a thrown ingot. Normal loading and handling practices will have no bad effect on the crucible.

We hope that the inputs below will enable the end users to get the utmost performance from their crucibles.

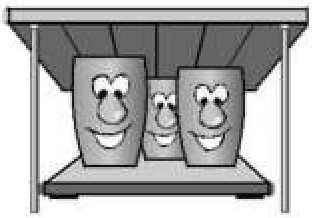
In most cases, these few precautions should result in savings in crucible cost (due to failure), cost of installation of new crucibles and less work in maintaining the crucible and hence liquid metal in a good, clean operating condition.

General Handling of Crucibles:

1. Always inspect the crucibles immediately after receipt and prior to use for any possibility of transit damage. The damage/ hair line cracks may lead to crack/ leakage failures in practice. They should better be cross checked with your supplier/ manufacturer. If the protective glaze is damaged excessively, the glaze damage will propagate and lead to faster/ premature oxidation of the crucible.

2. Store the crucible in a warm, well ventilated and dry place away from moisture. Crucibles are hygroscopic in nature and will absorb moisture from the atmosphere as well as from the damp floor.

3. Never store Crucibles directly on concrete, paving or on the ground, but store always on pallets. Best practice is to store them on wooden pallets without touching/ rubbing with each other.

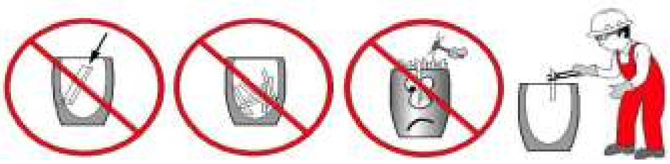


4. Never stack crucibles one inside another. Always stack them bottom up individually.

5. Never roll crucibles on the floor for transportation. Tools to transport should be padded. Rolling will damage the protective surface glaze leading to accelerated oxidation and in turn, loss of strength and premature failure.

Charging:

1. Place large metal ingots vertically into the crucible. Make sure that there is adequate clearance between metal ingots and crucible wall.
2. Do not wedge cold ingots inside the crucible. During heating, the metal will expand and cause bursting or tearing of the crucible.
3. On no account, should metal ingots be thrown into the crucible, as this will damage rim and wall of the crucible. Crucible is ceramic in nature and is prone to damage by mechanical shocks
4. Metal ingots or other heavy metal pieces should be placed carefully into the crucible using special tongs.



Charging Dos and Don'ts:

1. Ingots and bulky charge materials must be completely dried prior to charging.

2. The charging material should be placed loosely in the crucible, preferably with the smaller pieces (turnings and filings) on the bottom to cushion the larger ingots.

3. A liquid metal heel should be left in the crucible to permit faster melt down of the charge materials.

4. Avoid charging large, massive ingots to a small pool of liquid metal. This will cause a "chill back" or solidification of the metal, causing an immediate cracking of the crucible.

5. When the furnace is shut down, the crucible must be completely emptied. A heel of metal allowed to solidify may burst the crucible at the next heat up due to variance in expansion rates between the crucible and the metal heel.

6. If charging with liquid metal, avoid overfilling the crucible.

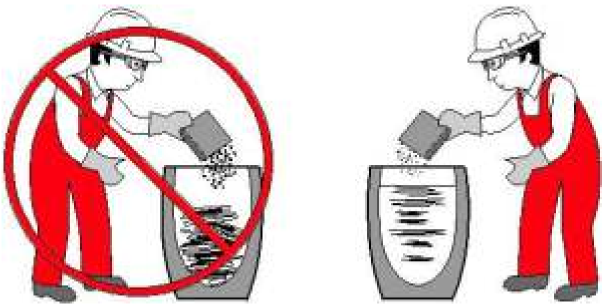
Fluxing Dos and Don'ts:

1. Never put any flux in an empty crucible.

2. Only place the flux in the middle of the bath of molten Aluminum.

3. Never charge ingots and flux at the same time into an empty crucible.

4. Wrap the flux in Aluminum foil. Plunge the Aluminum foil wrapped flux in the middle of the bath with a plunging cup.



5. Choose a flux which is less aggressive and corrosive

6. Granulated fluxes are friendly towards crucibles, since they generate dry dross, they are required to be added on low addition rates and are very less exothermic

7. Use an appropriate flux like COVERAL 88 in appropriate quantities for cleaning the buildup on walls; clean the walls regularly. Dross once built up is very difficult to remove and extensive effort to remove it will tend to damage the crucible.

8. Add fluxes sparingly.

Slag & Dross Build Up:

1. Slag and dross develop on the metal bath and coat the crucible. When first produced, the dross deposits are reasonably soft and fairly easy to remove. When the deposits are allowed to remain, they become extremely hard and difficult to remove. The buildup should therefore be removed immediately.

2. Buildup of Dross should be removed regularly using appropriate wall cleaning flux like **COVERAL 88** in adequate quantities. Excessive usage would cause faster erosion of the walls as the flux can then attack the crucible material.

3. Layers of slag/ dross on the crucible wall will inhibit crucible conductivity and is one of the most common causes of early crucible failure.

4. Aluminium dross will expand 8 to 10 times than the crucible material, thereby tearing the crucible and reducing its life. It is therefore mandatory that proper cleaning of crucible is done.

Cleaning Dos and Don'ts:

1. Proper dross removal is very important. Leftover dross will have a tendency to stick to walls and reduce the conductivity and life. The crucible should be thoroughly but carefully scrapped after the first heat while it is still hot.

2. Subsequently, the crucible should be scraped at the end of each day.

3. A proper tool that has rounded edges and a curvature similar to the inner wall of the crucible should be used to clean the crucible.

4. Slags and dross also contain flux material and increase the danger of the flux attack.

5. Dross is an insulator. The deposits will cause longer melt times, higher fuel consumption and reduce crucible capacity. This insulation will lead to oxidation and cracking.

Pouring Dos and Don'ts:

1. Always use an appropriate grade of flux which will produce non-sticky and dry dross. Granular fluxes for Aluminium and certain Drossing fluxes for Brass and Bronze produce less of the dross and make it powdery, so that it does not get built up on crucible walls

2. Once the metal has reached the required casting temperature and has been treated with flux and degassed as necessary, it should be poured as quickly as possible.

3. Holding metal at high temperature for very long time in the crucible is not advisable as it leads to reduced crucible life and to poor metallurgical quality of metal.

4. For a tilting crucible, it is considered poor practice to hold a crucible in the pouring position with the heating medium on. This

leads to gas pick up, metal loss, and uneven wall erosion, leading to premature failure.

5. When taking small quantities of metal from a tilting crucible furnace, the crucible should always be returned to the vertical position in between pours.

6. Crucible handling equipment must firmly and adequately support till the bottom of the crucible at all times, while it contains molten metal.

After Use Care:

Whenever a crucible is taken out of service due to an alloy change or furnace repair etc. with the intention of returning the crucible to service at a later stage, the following things should be considered.

1. Never allow molten leftover metal to solidify in the crucible. Pour or bale out any molten metal before shutting the furnace down. The solidifying metal in the crucible will expand 6 to 8 times more than the crucible material. As a result, if a heel of frozen metal is allowed to remain in the crucible when the crucible is heated up, the metal is warmed and expands at a greater rate than the crucible resulting in cracking.
It is frequently stated that a small heal can be tolerated and that with this we must agree. But the point is, how small must the heel be in order to be sure that it cannot do damage? The best solution is not to have any heel. Where it is absolutely essential to freeze a heel of metal in the crucible, a piece of gate or an ingot should be placed upright in the heel

1. While still hot, remove any dross build up by scrapping, using proper tools to avoid any damage to the crucible walls.

2. For gas or oil-fired furnaces, completely shut off all blowers so that cool air is not impinging on the crucible exterior. This impingement results in oxidation and cracking.

3. Always allow the crucible to cool naturally to room temperature. Attempts to speed up or slow down the natural cooling rate may result in thermal gradient induced cracking or increased oxidation.

4. When removing the crucible from the furnace, use proper equipment for handling, so as not to damage the crucible or its glaze. Any chipping of the exterior glaze coating can reduce crucible life due to localized oxidation.

5. Do not set a hot crucible on a cold surface. This could result in bottom cracking or spalling.

6. If a little molten metal remains in the bottom of a large diameter crucible, set the crucible at an angle to allow this molten metal to solidify on an angle and in a small area. This will reduce the likelihood of cracking during reheat, and will allow for the easy removal of this small, partially frozen metal heel.

7. Rough handling can result in cracks, which may or may not be readily visible prior to reheating.

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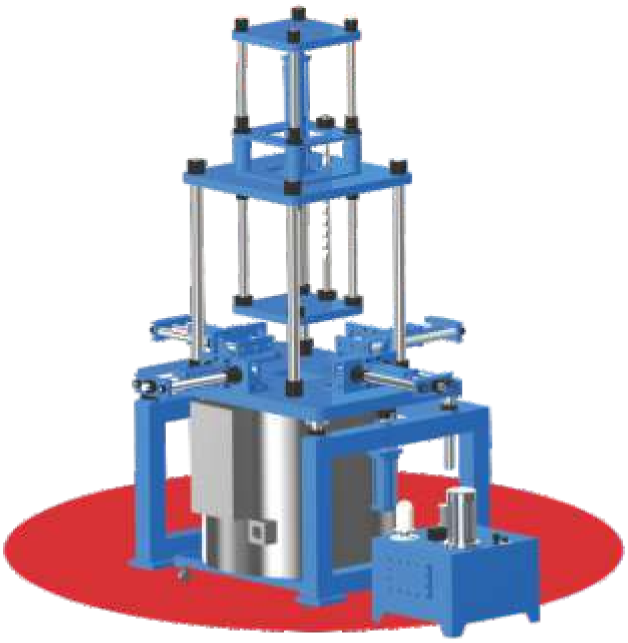

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Great Diecasting Technology Forum

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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Prediction of Distortion in Thin-Walled Die Castings

MAGMA GmbH, Germany

With the production of thin-walled, complex structural components made of aluminium and magnesium alloys, the foundry industry has succeeded in substi- tuting many classical sheet metal compo- nents by castings. These structural com- ponents do not only feature complex geometries but also superior strength and ductility properties, which make for a good safety performance in a crash event. Due to the fact that the section thick- nesses are very small in relation to the overall component sizes, compliance with dimensional tolerances used to be a manufacturing challenge that could often only be achieved by straightening. However, such straightening operations are costly and impede to the process flow. Therefore, the objective must be to control the development of distortion throughout the complete manufactur- ing chain in order to avoid the straightening step.

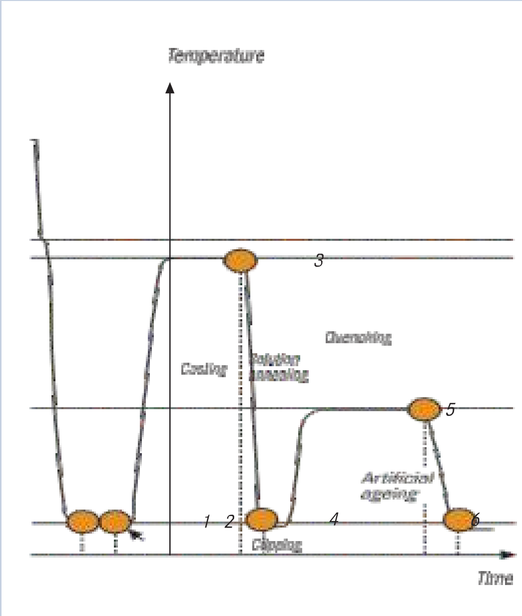
This requires profound knowledge of the mechanisms that control the devel- opment of distortion in all stages of the manufacturing chain as well as knowl- edge of how these mechanisms interact. Due to the wide range of parameters to be considered and taking into account a reasonable effort in terms of time and cost, this can only be accomplished by means of process simulation.

Development of residual stresses and distortion during structural casting production

The number of process steps required for the production of structural com- ponents depends on the selected alloy. Usually two types of alloys are used; nat- urally aged alloys such as Al Mg5Si2Mn and artificially aged alloys such as Al Si10MgMn.

In case of the naturally aged alloys, the manufacturing route consists of the process steps casting and clipping; in Case of the artificially aged alloys of casting, clipping, solution annealing, quenching, and artificial ageing (Figure 1). Each of these process steps influences the distortion of the castings.

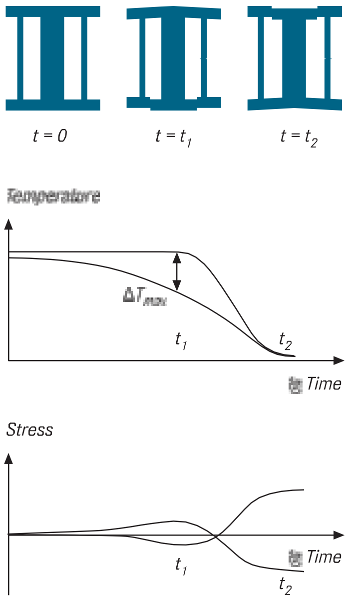
Figure 1



Temperature curve during the production chain of thin-walled structural castings

During casting (number (1) in Figure 1) and quenching (4), distortion occurs as a result of inhomogeneous cooling down to room temperature leading to inhomogeneous shrinkage. If the tem- perature-dependent thermal shrinkage of fast-cooling areas is impeded, tensile stresses develop in these areas. Due to the – at high temperatures – low strength of the casting, stress relief takes place as a result of plastic defor- mation. At the highest temperature gradient between slow and fast-cooling areas of the casting, the stresses and/or plastic deformations reach their maxi- mum values. When the plastic elonga- tions during solidification or cooling Exceed the yield point of the material, cracking occurs in the casting.

Figure 2



Underlying mechanism for the development of residual stresses and distortion by the example of a stress lattice

As cooling proceeds the temperature gradient between slow and fast-cooling areas decreases. This results initially in stress relief, and subsequently in a sign change of the stresses. The reversing stress condition is caused by the plastic deformations due to stress relief at high temperatures. After cooling down, thin-walled areas of the casting are exposed to compression, whereas thick-walled areas are exposed to tension stresses [1]. This stress formation mechanism is illustrated in (Figure 2) by way of the stress lattice.

The residual stress distribution that prevails after the casting process (1) changes during the subsequent clipping process (2). Consequently, the distortion of the casting will change. Additional stresses may occur due to machining or clamping forces. In the worst case, crack- ing already occurs during machining of the casting [2].

During solution annealing (3), the material strength decreases dramatically. The residual stresses from the casting process are almost completely relieved by creeping during the heat up process. Especially in structural components the dead weight alone leads to permanent deformations, i. e. distortion. As de- scribed above, new residual stresses and distortion occur during quenching (4) due to inhomogeneous cooling. For the production of structural castings, air quenching is a frequently applied method that causes only little residual stresses and distortion. The final artifi- cial ageing process (5) can lead to a par- tial relief of the residual stresses; howev- er, this only happens if the residual stresses exceed the minimum value required for the activation of creeping. In structural castings this is usually not the case.

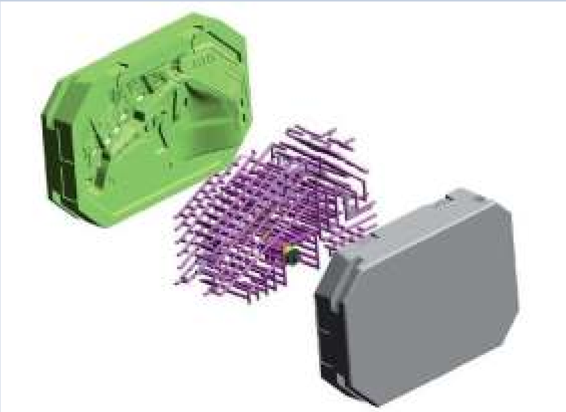
The development of distortion during casting and clipping will now be described and discussed by way of the example of a door lock panel for a pre- mium class passenger car. The distor- tions calculated for both process steps will be compared with measurements. Based on these values, possible solutions to reduce the development of distortion will be presented.

Calculation of distortion after casting a door lock panel

The calculation of distortion can be subdivided into two steps. In the first step, the casting and die temperatures are calculated by simulating the mold filling and solidification processes. In the second step, the temperatures are used as loads in the stress calculation. Decisive factors for precise calculation of distortion are the knowledge of the tem- perature-dependent and microstructure- related mechanical properties of the casting material as well as the considera- tion of shrinkage constraints caused by the die.

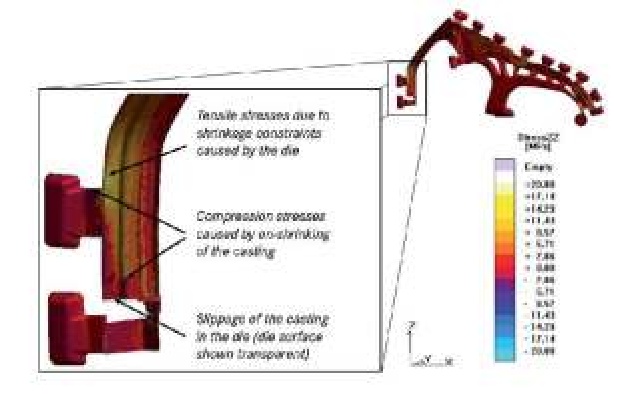
CAD model and enmeshment. The starting point for the simulation is a 3D model of the casting geometry including gating system, overflows, heating and cooling circuits, as well as the die casting tool (Figure 3). For the subsequent cal- culation, the complete geometry model will be enmeshed.

Figure 3



CAD model of the casting including runner system, cooling and heating channels and the two die halves

Figure 4



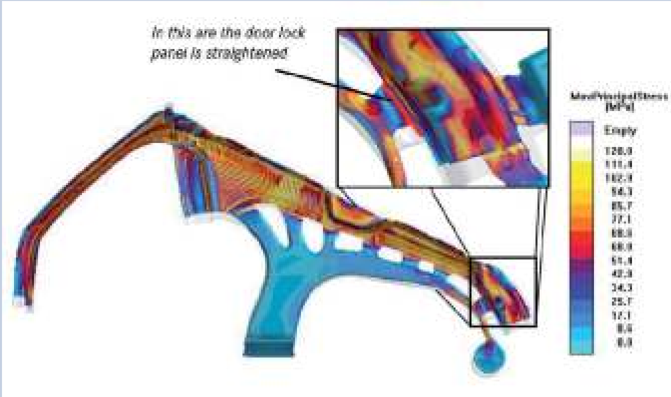
Stress distribution in the z direction in the door lock panel during cooling in the die

Mold filling and solidification simulation.
The simulation takes into account all relevant process parameters such as shot curve, temperatures of the molten metal, heating channel, and die, as well as the timing of the casting cycle including spraying of the release agent. As the simulation represents the real casting conditions, it also displays the "warming up" of the tooling during a number of cycles. Consequently, the mold filling, the solidification, and the cooling of the casting are calculated.

Calculation of residual stresses and distortion. In subsequent stress calculations, the calculated temperatures are taken as external loads acting on the casting and the gate. The areas with the highest cooling rates start to contract immediately after solidification. Contraction is at least partly constrained by the die. In such areas tensile stresses build up in the tangential direction **(Figure 4)**. At locations where the casting shrinks onto the die, compression stresses normal to the surface arise. Due to the very low strength values prevailing at these temperatures, stresses are still very low at this point. As cooling advances and strength values increase, the stresses start to rise markedly. Immediately before being removed from the die, almost the complete cast frame is subjected to tensile stresses. **(Figure 5)**.

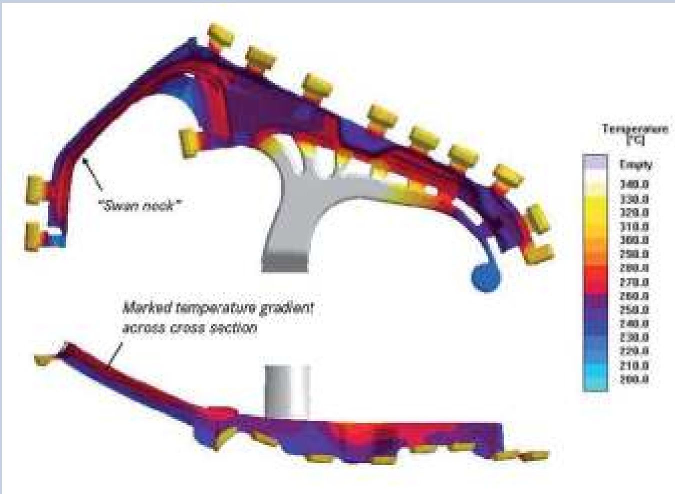
After releasing the casting from the die, the constraining effect of the die no longer exists giving the casting freedom to distort. Only the gate prevents the casting from contracting. This effect causes the casting to be contracted towards the gate. The temperature condition at the process stage "Removal from the die" forms the basis for the build-up of stresses and deformations during cooling down to room temperature **(Figure 6)**.

Figure 5



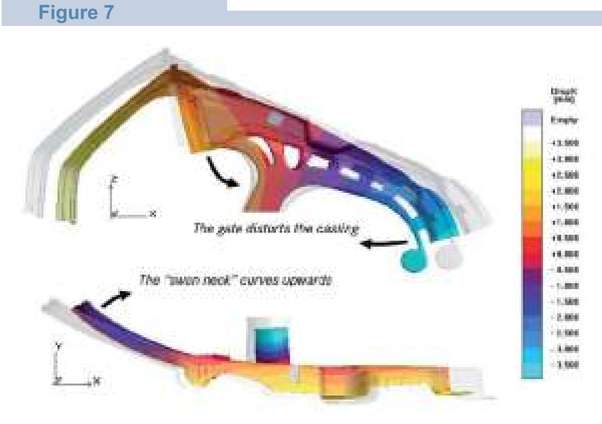
Maximal tensile stresses immediately before casting ejection. For illustration purposes the deformed and the non-deformed (transparent) geometries are shown.

Figure 6



Temperature distribution in the casting and in the gate after ejection.

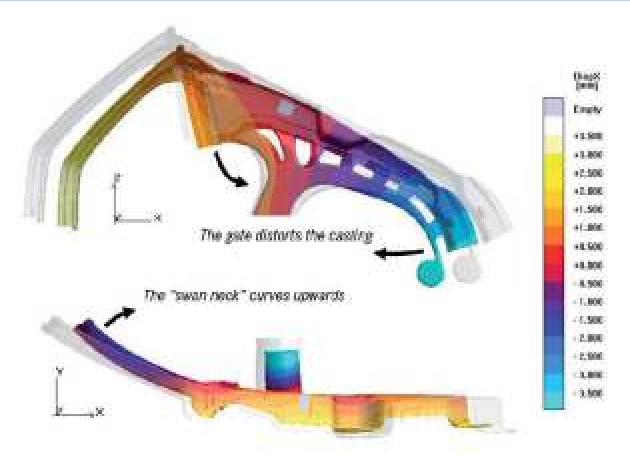
Figure 7



Deformation of the casting after cooling down. For illustration purposes the deformed and non-deformed geometries of the casting are shown.

During cooling, the contraction of the casting towards the gate continues (Figure 7). The so-called "swan neck" is pulled upwards, because after removal from the die the upper side of the door lock panel facing the biscuit is warmer than the lower side.

Figure 7



Deformation of the casting after cooling down. For illustration purposes the deformed and non-deformed geometries of the casting are shown.

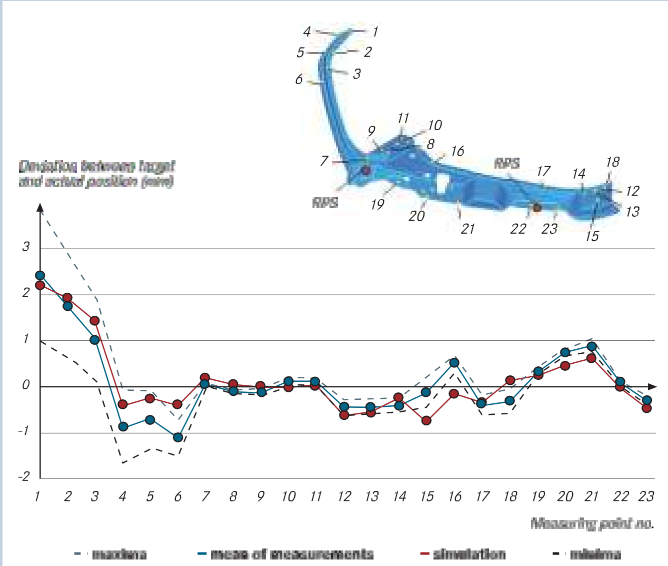
Processing the simulation results. In practice, distortion is measured by means of a coordinate measuring machine, which measures the displacement of the actual geometry from the underlying tar- get geometry for selected points. However, in the simulation the shifting of the elements (or nodes) is calculated in relation to the starting geometry. Therefore, the results from measurement and calculation cannot be directly compared.

To enable comparability of the results, the measurement operation needs to be recalculated. For this purpose, in a first step the deformed mesh is positioned on the reference points of the distortion measurement. This involves an iteration process because the positions of the reference points on the deformed casting are not known. As soon as the deformed mesh has found its final position, the distances of the measured points from the target geometry can be determined in a second step.

Comparison of measured and calculated deformations. Figure 8 shows the deviations from the target geometry for 23 measuring points after casting. The plotted curves represent the mean of all 15 measurements (blue curve), maxima and minima of the measurements (dot- ted lines), and the simulation results (red curve). Also the positions of the measur- ing and reference points (RPS) are given.

It is evident that there is a very high degree of coincidence between calculated and measured distortions.

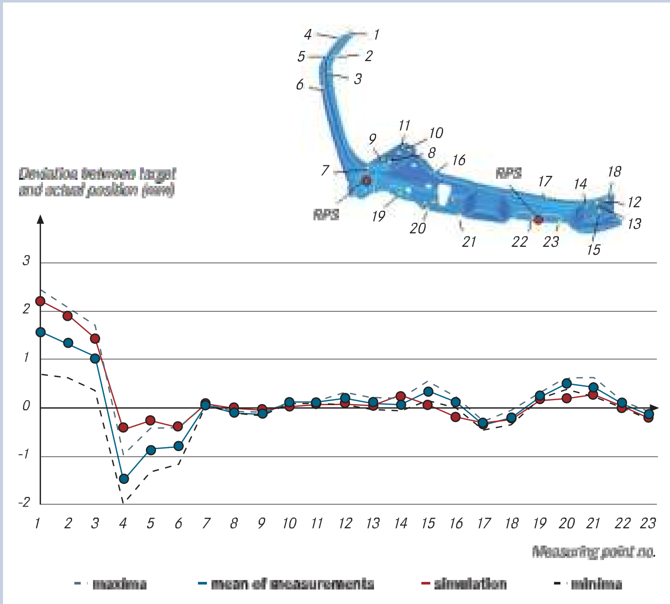
Figure 8



Measured versus calculated deviations from the target geometry for 23 measuring points of the door lock panel

Upon clipping of the gating system the casting springs back (Figure 9). Nevertheless, some curvature towards the gating position remains. Generally, the values of measured and calculated distortion are highly congruent.

Figure 9



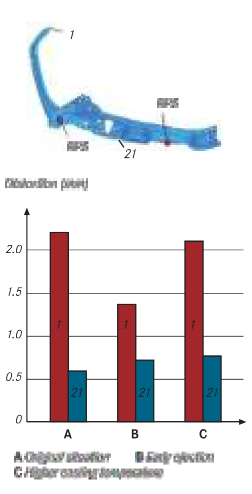
Calculated versus measured distortion after clipping

Measures to minimize distortion. After having successfully proved the coincidence of calculation and measurement, the next challenge is the mini- mization of distortion. For this purpose a parameter analysis was conducted:

– Influence of the ejection time (the door lock panel is removed from the die after 16 s already, not after 24 s);
– Influence of the casting temperature (the casting temperature is increased from 640 °C to 690 °C).

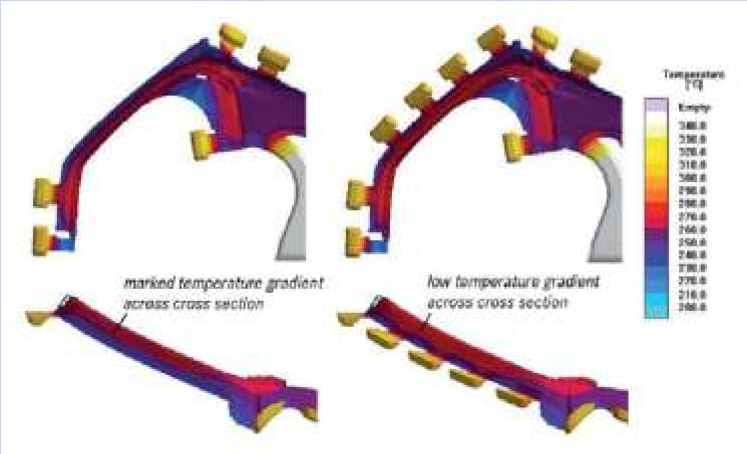
The earlier removal of the casting from the die reduces the temperature gradient across the cross section of the "swan neck", decreasing the distortion by approx. 35 % at measuring point 1 **(Figure 10)**.

Figure 10



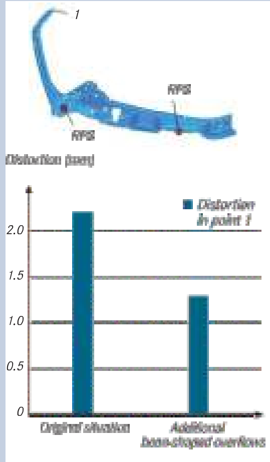
Parameter sensitivity of distortion calculated for the measuring points 1 and 21

Figure 11



Effect of additional overflows on the temperature distribution in the "swan neck"

Figure 12



Effect of changed temperature distribution on the distortion of the "swan neck" after casting

On the other hand, the temperature gradient between the runner and the casting after 16 s is still somewhat higher than after 24 s. This slightly increases the distortion at measuring point 21 from 0.6 mm to 0.75 mm (25 %). A higher casting temperature has a similar qualitative effect. However, distortion is reduced by only about 0.1 mm at measuring point 1. The parameter analysis shows that the distortion cannot be reduced merely by modifying the process parameters. The main cause for the distortion of the "swan neck" is the local temperature gradient across the casting cross section. Therefore, in a second step it was tried to reduce the temperature gradient by adding bean-shaped side recesses to the cold edges **(Figure 11)**.

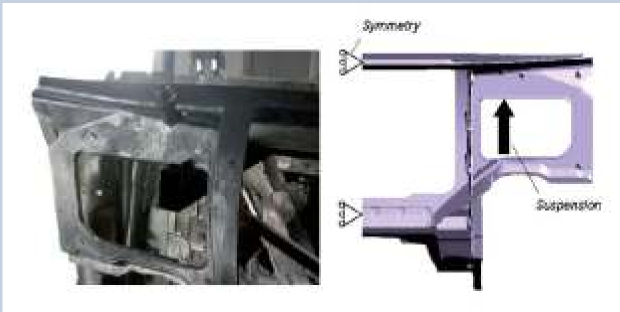
According to the calculation this measure alone reduces distortion by 42 % **(Figure 12)**.

Calculation of distortion in heat-treated bulk head

In the following, the development of distortion will be described and discussed by way of the example of a bulk head for a premium-class car. The calculation of the distortion is concentrated on the process step of solution annealing, because previous measurements of the other process steps have demonstrated that the solution annealing process is the key factor for the casting's overall distortion.

For the heat treatment the bulk head is suspended on both sides, as illustrated in Figure 13. The simulation takes into account the symmetry of the casting geometry and the suspension situation.

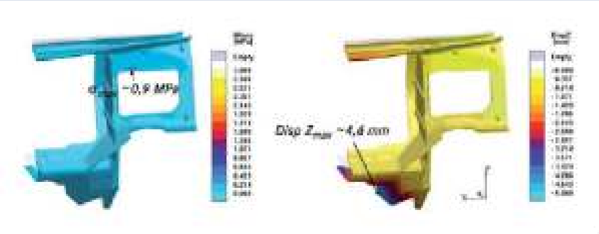
Figure 13



Suspension of the bulk head during heat treatment

Figure 14 shows the stress and deformation condition after solution annealing. Whereas the maximum stresses reach only 0.9 MPa, the maximal displacements about 4.6 mm.

Figure 14

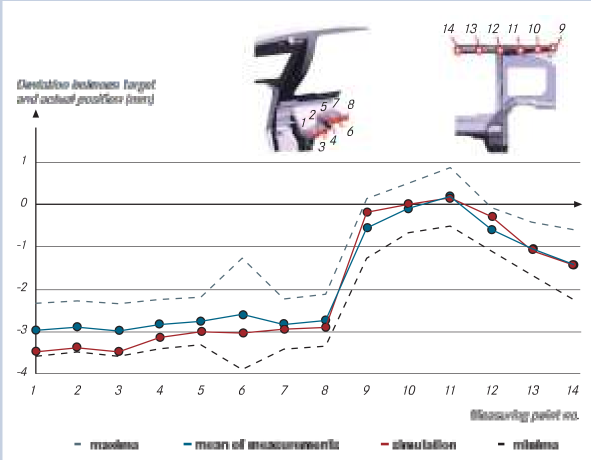


Stress distribution and deformation of the bulk head after solution annealing. The non-deformed bulk head geometry is shown transparent.

The calculated dimensional deviations as well as the mean, maximum, and minimum measured values are plotted in Figure 15. The calculated distortion values for the bulk head are very close to the mean of the measurements .

The capability of controlling distortion of thin-walled structural castings is a highly challenging manufacturing task that can only be solved if the mechanisms of distortion development and its specific effects on the casting are well understood. Modern simulation techniques nowadays enable precise prediction of distortion caused by the casting process, clipping, or heat treatment. Based on the obtained results it is possible to derive suitable optimization measures, which might be geared towards the manufacturing process or the design of the casting. Typical casting process related measures include an optimized design of the runner system (to minimize contraction towards the runner), the optimization of the time until casting removal or of the thermal conditions and pre-correction of distortion in the tooling. Distortion during heat treatment can be minimized by appropriate holding frames, the development of which should be supported by modern simulation techniques.

Figure 15



Calculated and measured distortion of the bulk head after heat treatment

Simulation using the described inno- vative computation solutions supports the die caster in manufacturing high-quality thin-walled structural castings

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[2] Wieckowicz, P.; Olive, S.: Residual Stress and Casting Cracking during Machin- ing. A Case Study. MAGMAtimes 03/2003, Vol. 8. MAGMA GmbH, Sept. 2003.

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From the President's Desk

Greetings Dear Friends,

It is indeed a pleasure and honour to be get an opportunity to serve GDCTECH, our association of very eminent members of the die casting industry.

The association has been ably led by the Past President, Dr. Aniruddha Karve. I would like thank Dr. Anirudh Karve for his contribution in building this organisation. I personally cherish and respect his views on various matters and would continue to benefit from his wisdom as a member of the Executive Board.

Friends, our nation has made tremendous strides in various fields. However, we have a long way to go. Many challenges still exist, not necessarily of equal measure or kind but complex. Whether it is COVID 19, which is in many ways a defining moment in the course of human history or the technological/internet driven revolution facing us, there is quite a handful of challenges to tackle and ride over for success. Industry 4.0 including IOT, AI, Blockchain, EV etc. maybe unsettling developments for some but do offer great opportunities. I am sure that we shall all along with the coming generations of Indians will take this nation to its rightful place in the near future.

Any change tends to disrupt our ways of thinking and approach to our life. We constantly need to adapt to and embrace these changes and move ahead with greater determination and ingenuity to achieve success. Every change is also an opportunity in disguise. However, making sense of all changes and riding them alone can be quite an arduous task. The need of the hour is to engage, connect and collaborate with each other to succeed. In most times, but especially during current times an association like GDCTECH can help provide a platform where we can collaborate to not just weather the situation but emerge stronger than ever as an industry and individuals.

GDCTECH exists for its members and must be crafted and developed further for the benefit of its members. Through several deliberations and sound advice from our colleagues, members and Advisory Board our Vision, Mission and Activity Programme has been developed. All efforts are directed to:

1. Engage more actively with members and other relevant stakeholders

2. Enhance and enlarge contribution in areas of technology, business processes and skill development. We must make our workplaces attractive for new talent and showcase our industry well. We all know that the new generation is skewed towards the new age businesses of IT etc. However, we need to keep making an effort to drive insights and understanding of our industry amongst the new generation.

3. Excellence in all areas we chose to drive. This is something very close to our heart. Quality rather quantity is important in what we do as an association going forward and we shall be constantly reviewing our programmes in terms of the benefit they bring and also the quality they deliver

In the coming period, our programmes will focus on:

- Technology and business processes
- Learning and skill development
- Forums for buyer seller interactions
- Events for showcasing and sharing
- Networking

Through this Journal I appeal to all our members to engage frequently and deeply with the Executive Board, Committees and other forums of the organisation. The association will strengthen with your maximum participation and create more value every day. Please do extract some time from your very busy schedules to connect and participate actively. We look forward to your suggestions on how we can make GDCTECH even stronger.

I wish you well and hope to meet you in person when the situation allows. Please stay safe and healthy. Good luck.

Sanjay Mathur
President
GDCTECH FORUM

GREAT DIECASTING TECHNOLOGY FORUM PROUDLY PRESENTS A NEW ENTHUSIASTIC TEAM

........To serve the Diecasting Industry

In the AGM held on 14th August 2021 a new team took over the batten of the Forum

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In the subsequent Board meeting, it was decided to focus on the following activities:

- Members Engagement
- Support the Zonal offices to promote the services of the forum
- Manpower development i.e. Training
- Promotion among Educational institutions to motivate aspiring students to join the diecasting industry

The following committees have been formed:

Membership Development / Members Engagement	Advait Athavale
Training	Madhav Athavale
Solution Centre	Shreekant Bhat
Journal	Anand Joshi
Buyers Committee	Deepak Mahajan
Coffee Talk	Aniruddha Pandit
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Project and Casting Competition	Anand Joshi
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Annual Event	Anil Kulkarni
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Annual General Meeting Glimpses

Past President Dr. Aniruddha Karve introducing New President Mr. Sanjay Mathur

Mr. Sanjay Mathur addressing the audience

Mr. R. T. Kulkarni expressing his thoughts

Attentive audiene

Mr. Sanjay Mathur introducing Vice President Mr. Anil Kulkarni

Mr. Sanjay Mathur introducing Executive Board Member Mr. B. B. Lohiya

Members at Annual General Meeting

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Prof. P. R. Khangaonkar

His Dedication & Love Towards Foundry Industry will always have Footprints in our hearts.

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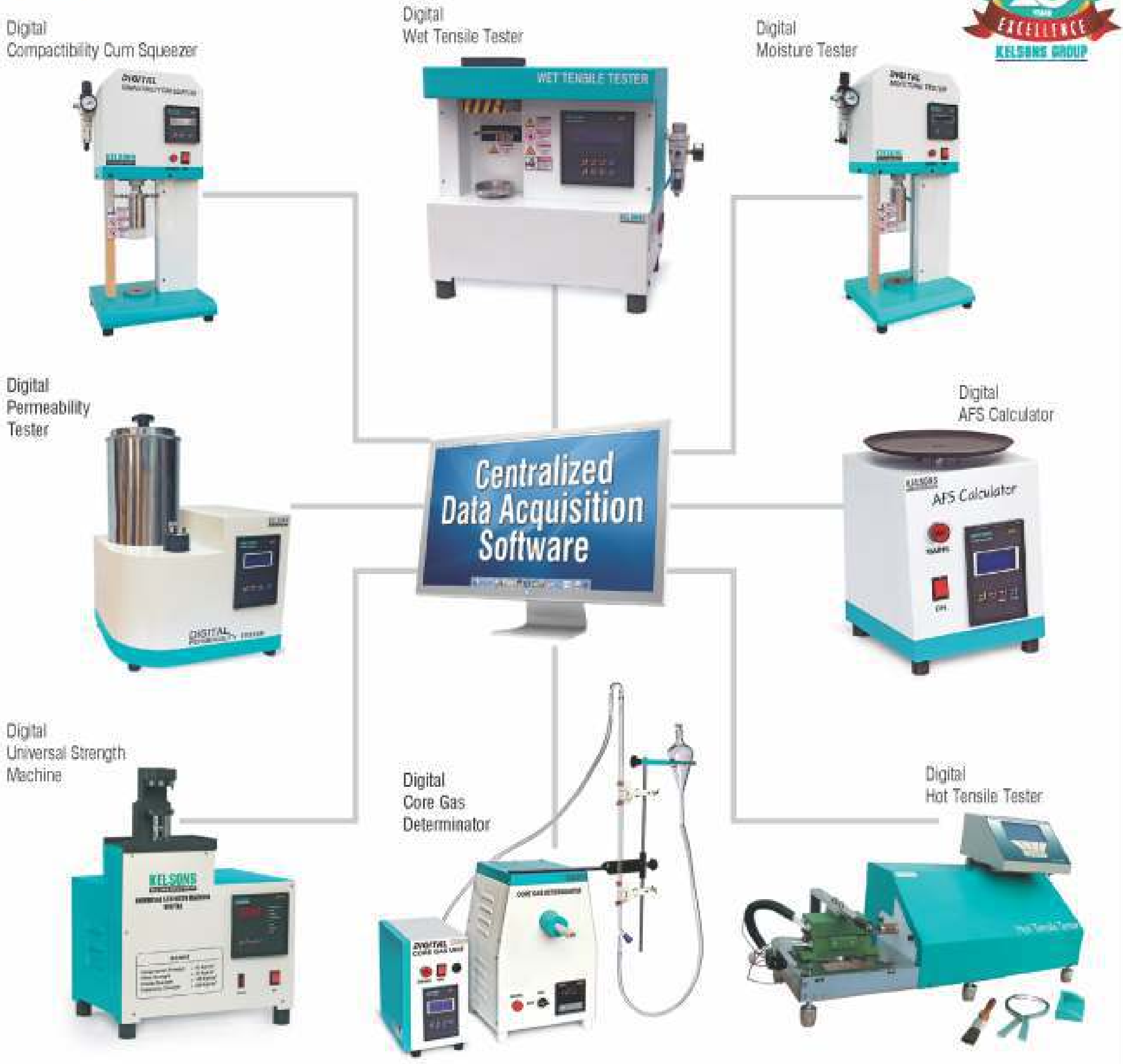

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IMPORTANCE OF DIE LUBRICANTS IN HIGH PRESSURE DIECASTING OF ALUMINIUM ALLOYS

Madhav Athavale - Consultant, Email : athavalemadhav@gmail.com

Content

1. Introduction - Casting design trends
2. Meeting casting buyer "needs"
3. Aluminium Alloy - Die interactions in HPDC process
4. Role of die lubricants and their evolution
5. How to select proper die face lubricant?
6. Application of die face lubricants
7. Plunger lubricants and their application
8. Testing of die lubricants
9. Casting defects connected with Die lubricant
10. Conclusions
11. Annexures and Tables and Pictures

1.0 Introduction: Component design trends – Lighter, Tighter, Lesser, Cheaper

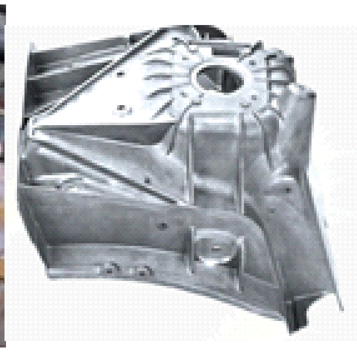
Component designers and buyers want Dimensions and Properties at Lowest possible cost. While designing the components for use in various industries like Aerospace for aircrafts and space ships, automotive vehicles like two wheelers, cars, commercial vehicles, mass transportation systems like trains, business machines like computers etc the trend is to aim for low weight while meeting all the functional requirements.

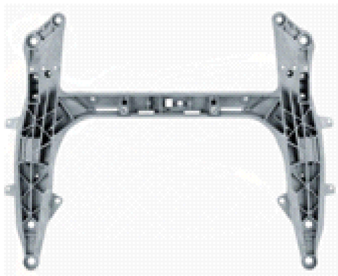
Main reasons for light weighting are to attract the user by providing energy efficiency and costs associated in running the system, meeting stricter environmental norms, reducing the carbon foot print and getting associated economic benefits.

This is achieved through

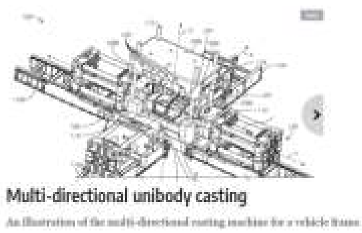
1 Use of higher strength but lower density materials and alloys e.g., amongst metals move from iron or steel to Al, Mg or Zn alloys or use of composite materials and plastics in aircraft, automotive vehicles, railways etc.

2 A thin walls to reduce weight and ribbed or hollow structures to achieve desired stiffness e.g., Housing/engine crank case/oil pans with thinner walls strengthened with ribs, Piston with cooling passage.



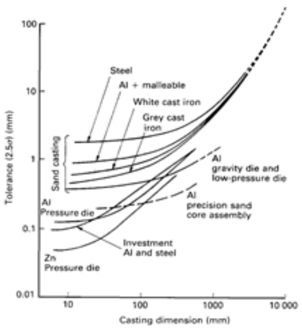


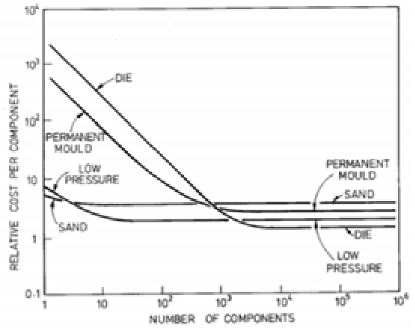
3 Combine multiple components into a single new component to reduce assembly costs e.g., Replacement of assemblies of multiple sheet metal components with a sin

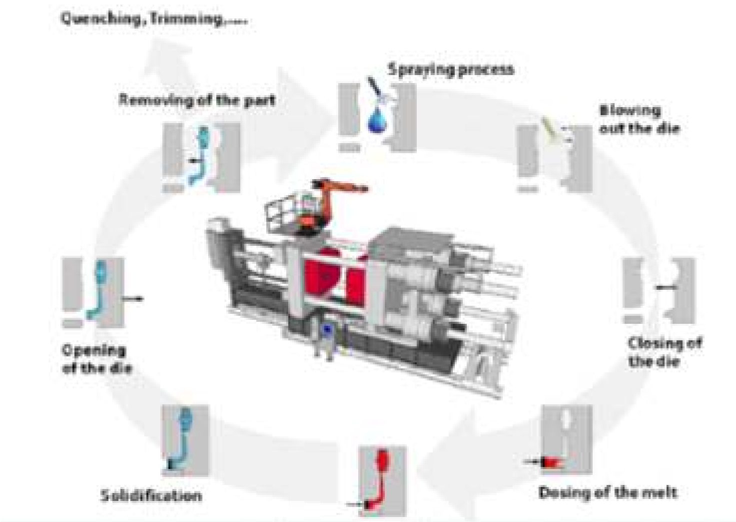


4 Use of production process that gives tighter dimensional tolerances and is cost effective to meet modern component machining and assembly techniques e.g., use machining center, robotics.

Figure below (from Foseco Foundryman's Handbook) shows comparison of dimensional tolerances for different casting processes for different materials.







High pressure die casting is very widely adopted manufacturing method for mass production of items like automotive components, electrical components, decorative castings etc. using aluminium alloys.

2.0 Meeting the Casting Buyer Needs

Meeting requirements of Dimensions, Properties means good control of the HPDC production process.

1. Dimensional accuracy – Translates to proper die design, well maintained die casting machine and good release of casting from die ensuring no distortion or cracking

2 Surface quality – Translates to absence of surface defects like erosion marks, die crazing or cracking, soldering, drag marks, surface discoloration or non-paintable surface etc. which are linked to thermal and chemical interaction between molten Al alloy and steel die.

3. Mechanical properties – Translates to absence of defects like gas holes, pin holes, cracks, inclusions and presence of right type of microstructure.

4. Costs – Translates to Smooth operation of HPDC process by way of long die life, less down time for die maintenance, shorter production cycle times, optimal die design and low consumption of different consumables used in the HPDC process.

3.0 Aluminium Alloy - Die interactions in HPDC process.

Diagram below depicts a typical HPDC process cycle. Preheated die is sprayed with die lubricant before dies are closed and molten Aluminium alloy is injected in the die cavity at high velocity and then metal is kept under high pressure during solidification. Die is opened after casting solidifies and is ejected from the die and then the next cycle starts.

Molten alloy in the temperature range of 670 – 710 Deg C is injected in the die at a velocity of 40 – 70 meters/second in the pressure range of 50-80 Mpa. Surface temperature of the die reaches around 400 – 450 Deg C with in a time of one second after metal injection. After casting ejection, when die is sprayed with a water base lubricant, the temperature comes down to 150 – 200 Deg C. Thus, there is a die surface temperature variation of around 250 Deg C through the cycle.

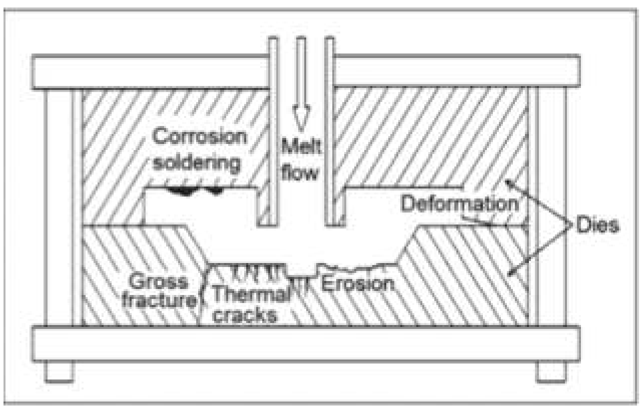
As can be seen, steel die is exposed to three types of attacks namely -

(I) Thermal shock and thermal fatigue causing formation of cracks

(ii) Erosion due to impingement of high velocity liquid metal

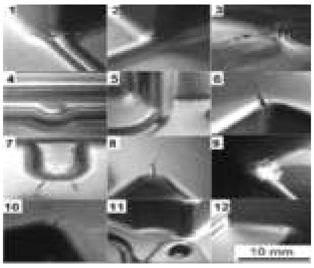
(iii) Chemical attack of Aluminium on steel die causing corrosion and soldering

Schematic below depicts where the die is affected



The pictures below show the appearance of these defects on die surface –

Die Crazing (Thermal Fatigue)



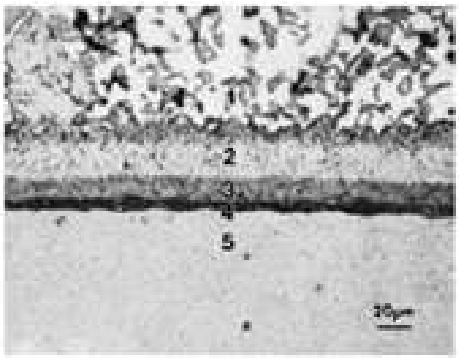
Die Cracking (Thermal Shock)

Die Errosion (Metal Impingement)

Soldering damage on a core pin

Soldering (Chemical Attack)

Soldering Mechanism - When die surface temperature rises higher than "Soldering Critical Temperature", *in absence of a barrier; like oxide film or a film of die lubricant*, iron dissolves in aluminium and aluminium start diffusing in iron forming intermetallic compounds. If the aluminium content becomes sufficiently high at the die surface a liquid aluminium rich phase comes in existence in contact with and in between the intermetallic compounds. On cooling it forms interlocked structure between die and casting joining casting to the die. Micrograph below shows section through solder area 1 A 390 Casting, 2 to 4 Various inter metallic phases and 5 H13 Die



1. A390
2. Al[illegible]FeSi
3. Al[illegible]Fe[illegible]Si[illegible]
4. Al[illegible]Fe[illegible]Si[illegible]
5. H13 substrate

Die soldering causes surface defects on the casting as above, may also result in difficulty in casting ejection or release, drag marks on the casting and in worst case distortion of the casting. More details of Soldering mechanism are in the Annexure 1

4.0 Role of Die Lubricant and their evolution

On the above background of Aluminium/Steel die interaction explained above one can say that a die lubricant is an essential part of the HPDC of Aluminium castings. A die lubricant must meet the following criteria -

(1) Parting Ability - Primary function of die lube is release, and this can only take place if an adequate amount of lubricant film is formed over the die surface. It must be possible to release the castings from the die surface without distortion or undue stress.

(2) Barrier Formation - The lubricant must form a physical barrier between the cast metal and the face of the die in a wide temperature range in order to reduce adhesion of the cast metal to the die surface (referred to as "soldering" or "galvanizing", depending on the metal being cast).

(3) Provide balanced film performance – Should have minimum or no carbon buildup in cold areas of the die while still protecting hot spots to prevent solder formation.

(4) Minimize machine downtime for removal of ex-cavity build-up.

(5) Soundness of Casting - The lubricant composition must not give off excessive amounts of gas which might lead to porosity of the casting surface and affect the pressure tightness of the castings.

(6) Health and Safety - It is important that lubricants do not contain dangerous or toxic components or components which will react to form undesirable by products.

Drivers for evolution of Die lubricant formulations
Die lubricant formulations and application techniques have evolved along with changing demands of castings and machines such as -

1. Non critical to critical castings so higher melting temperature alloys that are heat treated
2 Post casting treatments like painting
3 Need to have castings that can be assembled by welding, riveting or gluing
4 Large size castings so larger capacity HPDC machines, higher injection speeds
5. Complex geometries giving rise to more hot spot areas
6. More stringent work environment/emission norms
7. Continuous need to lower the overall cost of production

History of Die Lubricant formulation development
In the early days of die casting, various pastes, oils (mineral & vegetable), greases, and waxes were used and these were applied to the die by various means including brushing.

Mineral oil is a liquid by-product of refining crude oil to make gasoline and other petroleum products. This type of mineral oil is a transparent, colourless oil, composed mainly of alkanes[2] and cycloalkanes, related to petroleum jelly.

Vegetable oils are composed of triglycerides. The triglycerides are molecules that contain carbon, hydrogen and oxygen, and its structure includes glycerol and three fatty acids. The fatty acids present in triglycerides may be the same or of different types. One drawback is these oils tend to degrade in storage.

Additives such as aluminum paste and finely divided graphite are the constituents, but tend to cause surface staining which can be undesirable in many applications.

Later came Silicone oils. Silicone oils in some instances can be effective release agents, however under most conditions the silicone oils lack sufficient lubricant properties, especially for moving parts.

Problems with old formulations

1. Fumes and staining or discoloration of the castings
2. Buildup on the die faces themselves leads to inferior casting and surface staining, and shortens the overall life of the die.
3. Deposits on the outside of the die can be troublesome and difficult to remove, requiring mechanical abrasion in the absence of effective solvents.
4. Build up on the mating surfaces of dies can prevent complete closure of the dies, leading to dimensional inaccuracies of the castings.
5. Still further, hydrocarbon oils can cause the buildup of degradation products on the die faces and on the exterior of the dies.

In the initial days where HPDC castings were used for less critical applications, surface aesthetic was not important and castings were not painted above type of lubricants were tolerated. But things kept on evolving demanding changes in formulations.

Water dilutable emulsions as lubricants their physics and chemistry.

The casting types have been changing all the time, particularly in the automotive industry as was discussed above in the drivers of change.

- Engine blocks, instrument panels, complete door frames and now entire space frame are just some of the examples of aluminium components now being produced by die-casting. This has led to a trend towards bigger die-cast machines and larger shot weights. (Giga Press for Tesla Chassis Component – 100kg)

- Previously, the die surface temperatures before spray used to range between 250°C to 350°C. With the large components, the maximum temperature can be as high as 400°C while the cooler portions of the die may be as low as 220°C.

- This leads to the development of localized hot spots which, in turn, create solder problems. This places a greater dependence on the die lubricant to provide cooling for the die surface.

- Yet the higher temperatures encountered before the spray make this difficult to do because of the Leidenfrost effect. This requires greater quantities of die lubricant to be sprayed, which increase cycle times and costs.

Understanding Liedenfrost Effect

Relatively Low Hot Plate Temperature

Relatively High Hot Plate Temperature

When water is sprayed on to a hot surface, which is at a temperature well above the boiling point of water, it is unable to make contact with the metal surface. Instead, the drops of water appear to float on a cushion of water vapor and thus are unable to wet the surface Die lubricant active materials are thus unable to be laid down on the die surface. The highest temperature at which water, or water base die lubricant, can contact the metal surface is known as the Leidenfrost temperature. Many different factors affect the Leidenfrost temperature. Mechanical factors like the distance and angle of sprays, the size of the droplet and impact pressure all affect the wetting temperature. Last, but not the least, constituents in the spray can affect Leidenfrost temperature. Diagrams below explains the phenomenon.

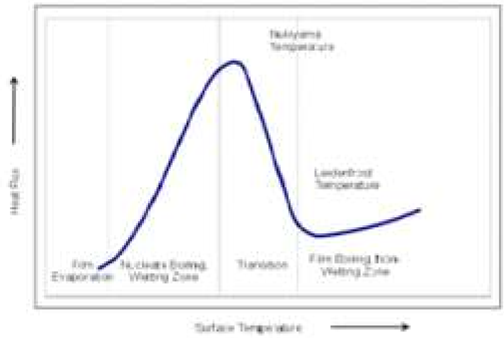
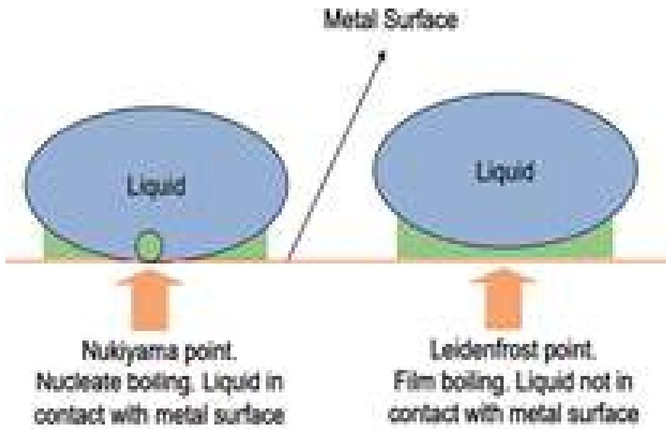


Figure 1: Change of heat flux with temperature in forced convection cooling due to spray impingement.



Die Lubricant film starts forming below Leidenfrost Temperature so Lubricant formulation has to raise the Leidenfrost Temperature. Initially emulsions using extreme pressure steam cylinder oils with appropriate emulsifying agents, synthetic waxes, silicone oils and defoamers and preservatives came in to vogue. These could be diluted with water and used effectively. These formulations served the purpose for some time.

As a needs of shining bright finish, painting ability & weldability became new requirement, the formulations with more synthetic ingredients for further improvement in performance. Some examples of materials are given ahead.

Ester oils exhibit chemical and physical properties which constitute a useful addition to the range of petrochemical derivatives

Synthetic waxes - Polyethylene and Polypropylene They have higher temperature resistance than oil and offer good flow promotion for molten metals and good adhesion, in particular in the gating area. Provide good demolding capabilities up to much higher tool temperatures than with the use of oils.

One has to be aware that release agents with a high wax content can cause deposits in the form of so-called oil carbon in the mold cavity.

R- Polysiloxanes (Paintable Silicones)
They work at highest temperatures. Their decomposition products can be removed very easily so visually flawless casting surfaces and a very good flow promotion for molten metal. They can be used at high dilution rates. It means least negative impact on subsequent operations like welding.

When using release agents with a high content of R-polysiloxanes, the lubricating effect will be lower than the releasing effect. This information is particularly important for die-cast components having even the smallest draft.

Just as wax components, R-polysiloxanes can, under certain circumstances, lead to deposits in the mold cavity.

Emulsifying agents - They are responsible for ensuring that the organic raw materials described above will produce a stable mixture in the aqueous phase.

Corrosion inhibitors - Used to protect the die casting machine and the casting tool against corrosion.

Biocide- For protecting the concentrated release agent against microbiological contamination and the associated separation that would cause demolding issues when diluted.

Defoamers - To prevent air entrapment and bubble formation

Wetting agents – To improve the adhesion of lubricant film with the die face.
Some of the typical formulations are given in Annexure 2

Other Developments

1 Electrostatically deposited power coatings as die lubricants have been tried for some time now however their use is not very wide spread.

2 With new commercially available oils and advances like micro spraying using programmable spay heads, the use of water-free release agents has also gained ground with the following benefits –
   (i) Lower spraying volumes result in fewer waste that needs to be disposed of and, due to the non-existing cooling effect of water-free release agents.
   (ii) The tool steel is not subject to the thermal stresses typical of water-based release agents which can lead to premature aging or damage to the hot-forming steel.

When using water-free release agents, adequate extraction systems are required above the die casting machine in order to prevent the resulting aerosols and vapors from escaping into the foundry. In addition, internal cooling channels have to be more effectively laid so as to minimize hot spots across the die face.

....To be continued in next issue

Upcoming Event

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