ALUMINIUM GDC TECH GREAT DIE CASTING

JOURNAL FOR ALUMINIUM CASTING TECHNOLOGY

Volume 40 - June 2020

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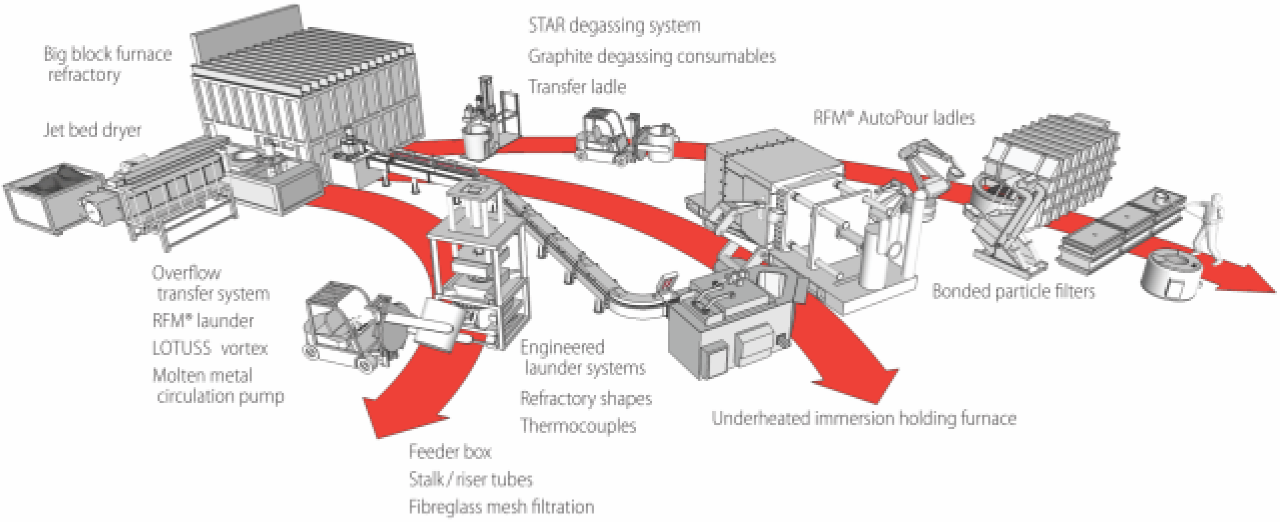

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From Editor's Desk

Dear Readers,

Very rarely in a human lifetime one experiences catastrophe of such enormous scale, which jolts the entire would in every aspect of life - so familiar to us since we are born. Almost everything around us suddenly came to standstill in last week of March 2020. People were totally perplexed and confused by arrival of COVID 19 - the name hitherto unheard of by most. With it came uncertainly and fear.

With passage of time, however, new knowledge and information brought some understanding of profound impact created by the virus and how we should be operating in the future. With progressive relaxation of lockdown restrictions, the activities have started limping back to some normalcy since beginning of June 2020.

Also learning from recent events, experiences over last three months and emphasis on "Atmanirbhar Bharat" are brining back hope of future which promises new opportunities

As any other, GDC TECH FORUM's activities also came to a sudden halt and the April 2020 issue of the Journal could not be published. Now we are also starting, albeit slowly, our activities and are pleased to release June 2020 issue though not in first week of the month as usual.

Industry, especially Aluminium Foundry Industry was and is passing through a bad patch and uncertain phase for quite some time. But we trust that we all together are here to stay ..and prosper.

Anand Joshi

DOSING FURNACE LINING WITH INSURAL PRE-CAST SHAPES REDUCES DOWNTIME IN FOUNDRIES

Author: Dirk Schmeisser, Foseco Europe

By using INSURAL pre-cast shapes for furnace relining, sintering can be dispensed with and a constant density index can be achieved. The use of high-quality insulating materials in the lining process enables significant energy savings and thus a reduction in CO_2 emissions.

INTRODUCTION

The relining of a dosing furnace in aluminium foundries is always labour-intensive and particularly time-consuming. In the case of a monolithic lining, the sintering phase in particular extends the downtime of the furnace. A market analysis among relevant customers shows that there is a need for optimisation in the area of furnace lining and cleaning of dosing furnaces in connection with corundum formation.

The solution for your dosing furnace in pressure and low-pressure die casting foundries: A completely dry lining with INSURAL pre-cast components combined with high-quality insulation materials.

THE FORMATION OF CORUNDUM

There are basically two types of corundum formation: external and internal corundum generation.

External corundum formation occurs on the bath surface by oxidation of liquid aluminium with oxygen from the furnace atmosphere. Aluminium is sucked upwards through pores and oxides on the metal surface and forms corundum-lumps. This process is accelerated by a high proportion of oxygen, the presence of certain alloying elements and high temperatures.

In addition, there is internal corundum formation, also called penetration. In the contact area of the refractory lining with the liquid aluminium, a substitution reaction occurs due to the higher affinity of oxygen to the aluminium in the molten melt and the free oxygen from the SiO_2 in the refractory lining. This reaction takes place within the refractory structure and below the melt surface. A dense black zone is formed. This is accelerated by a high bath temperature and an increase in the pre-baking temperature, which burns out non-wetting additives.

In order to solve this problem, extensive tests were carried out with various INSURAL recipes. Suitable compositions were then determined and new formulations developed. FOSECO offers a completely dry lining with INSURAL pre-shaped parts for all common dosing and low-pressure furnaces, which is not only economically attractive but also offers the following further advantages:

+ Direct installation on site possible
+ No time-consuming sintering required
+ Stable density index after relining is achieved in a much shorter time
+ Corundum formation is reduced to a minimum
+ Easy cleaning, thus alloy change with little effort possible
+ Larger filling volume for some furnace types due to optimized design
+ Energy saving during operation
+ Reduction of CO_2 emissions

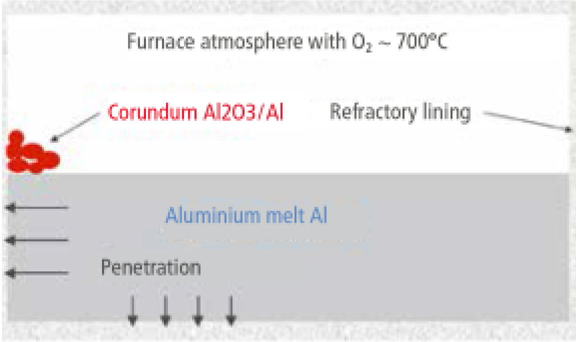

Figure 1: Schematic of corundum formation

THE INSTALLATION

The new lining consists of INSURAL pre-cast parts, which are assembled according to a modular principle. The time required for a furnace installation using a clean and empty steel shell is between two and four days, depending on the furnace type. In addition to the INSURAL pre-cast parts, high-quality insulation materials are used. The insulation materials are mounted between the INSURAL parts and the steel shell. After insulating the bottom area and the side walls, the main liner is inserted. The gap between the bassin and the insulation is then filled and the heating and ceiling blocks are placed on top. The remaining insulation work is then carried out and the holes for the thermocouple and the compressed air supply are drilled. The last step is closing the furnace with the lid.

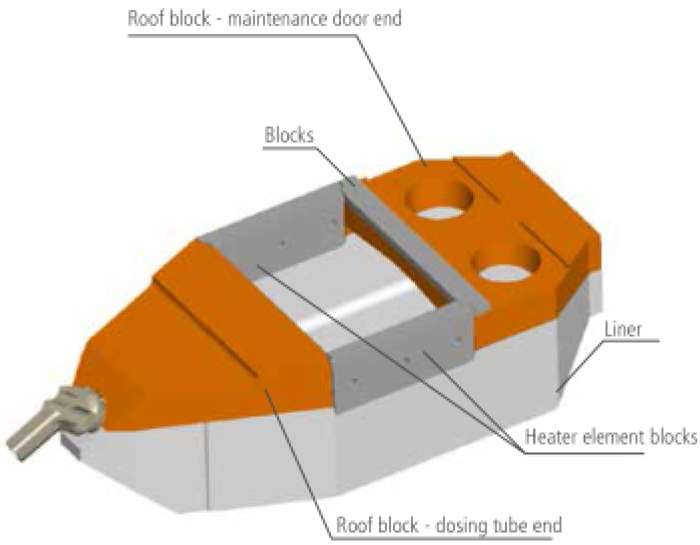

Figure 2: INSURAL precast components

Figure 3: Empty steel shell

Figure 4: Insulating materials for floor and side walls

Figure 5: Installation of the liner into the steel shell

Figure 6: Installation of heating and roof blocks

ADVANTAGES

After complete assembly, the furnace can be put into operation immediately and is ready for operation once the desired furnace chamber temperature has been reached. A sintering program as with a conventional installation is not necessary. As can be seen from Diagram 1, this step saves a great amount of time.

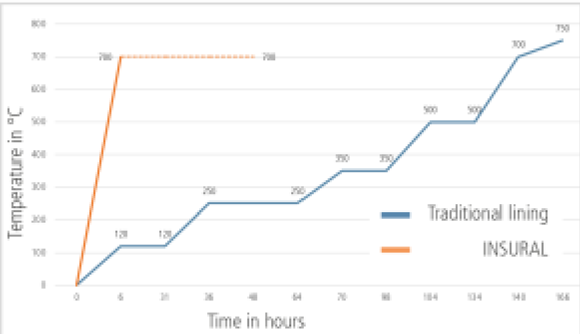

Diagram 1: Comparison of preheating curves

Depending on the casting process and quality requirements, the density index plays an important role in the availability of the dosing furnace. After reaching the furnace chamber temperature, a constant low density index value can be measured after only two days (Diagram 2). The availability of the system by lining it with INSURAL pre-cast parts has clear advantages over conventional lining. With conventional installations, the sintering process takes seven days. If INSURAL prefabricated parts are used, this part is completely obsolete.

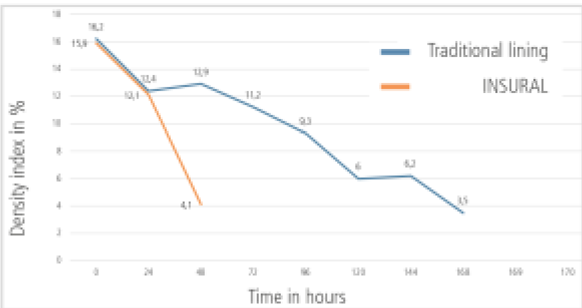

Diagram 2: Density Index

In addition, a constant density index is achieved much faster with an INSURAL lining. As a result, the furnace can return to the production process faster due to the shortened integration time.

The use of INSURAL prefabricated parts minimizes corundum formation and facilitates furnace cleaning. For this purpose, the method of corundum formation will be discussed once again. Parameters that can influence the formation of corundum are:

+ High proportion of O_2
+ Pores
+ SiO_2 ratio in refractory material
+ Temperature
+ Wetting properties

Based on these points, the INSURAL 270 recipe was developed in 2015, which has a small amount of SiO_2, low porosity and good non-wettability with liquid aluminium. With the INSURAL 270 recipe, dry lining with pre-cast parts for dosing furnaces has been successfully introduced to the market in recent years and excellent results have been achieved with a large number of customers.

INSURAL 270 has a SiO_2 content of 22 %, a porosity of about 17 %, a cold compressive strength of 50 N/mm² and excellent non-wetting properties compared to liquid aluminium. In order to meet the growing demands of the market, another INSURAL formulation has been developed, which has extended the product range since April 2019. The INSURAL 290 recipe has a SiO_2 content of less than 10 % only, a porosity of around 16 % and a higher cold compressive strength of 100 N/mm². The non-wetting properties remain excellent.

Another important point is the temperature in the furnace, which is a decisive factor for the formation of corundum. The compensation of temperature loss in dosing furnaces is controlled by the heaters and can be readjusted depending on the insulation. Since the heating takes place via radiant heat, the heating elements become significantly hotter than the melt bath temperature. This is a major reason why the formation of corundum accelerates and good insulation therefore has a positive influence on corundum avoidance.

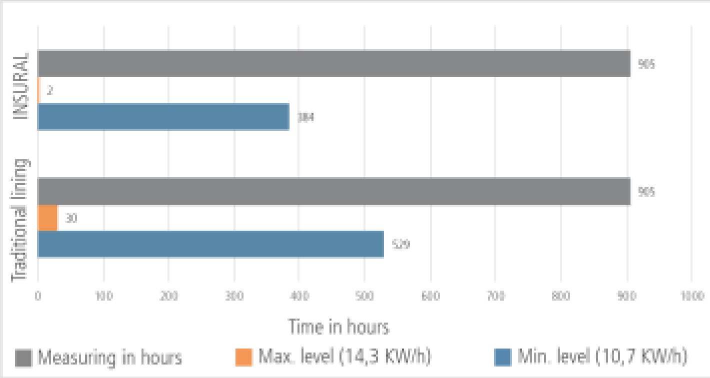

Diagram 3: Power consumption

Figure 7: Condition of furnace after 3.5 years

FOSECOs insulation concept can counteract corundum formation and also save energy costs (Diagram 3). The power consumption measurements carried out in a foundry using a 650 kg dosing furnace show a lower energy requirement compared to conventional lining. The heating power remains at the lowest level for almost 98% of the time, which avoids overheating and effectively prevents corundum formation. Operation at low heating output levels also has an influence on the peak shutdown in the foundry's energy management and reduces weekly average consumption.

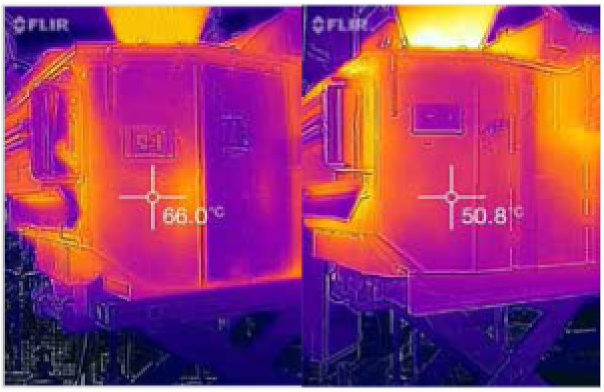

Figure. 8: Furnace surface temperature (left: conventional lining, right INSURAL 270)

CONCLUSION

Furnace lining with INSURAL pre-cast parts offers a number of advantages over conventional lining. On the one hand, the actual lining process requires considerably less time, and on the other hand, time-consuming sintering is no longer necessary. Furthermore, the dry lining avoids the absorption of hydrogen by the melt in the first days after commissioning. The formation of corundum is minimized and furnace cleaning is simplified. Furnace cleaning remains important, so a weekly cleaning interval is recommended. Depending on the insulation concept selected, energy and CO_2 output can be significantly reduced. The current electricity mix in Germany indicates that for 1 kWh an average of 511.2 grams CO_2 are released to atmosphere. With a furnace that saves 48,000 kWh per year, the foundry achieves a reduction of 24.5 tons of climate-damaging CO_2.

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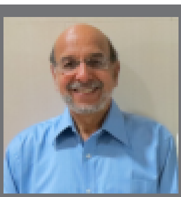

Management Of Calibrations

Vishwas Kale
Managing Director,
Vijayesh Instruments Pvt. Ltd, Pune
Email : vish1945@gmail.com

Most industries use the calibration services of their in-house facilities or of an external agency. However, it is observed that the calibration checks carried out are found to be inadequate later when inspected by the assessors. To avoid this in anticipation, some groundwork is necessary to be carried out. The information presented here is applicable to the user who wishes for any calibration work.

All those who are involved in this process wish to maintain the quality. Everyone contributes some view how best to achieve it. But it must be remembered that such points are not necessarily the requirement. For example, the shop floor engineer demands a tolerance in a parameter like temperature of + / - 5 degrees Centigrade while using the furnace, and the R & D engineer may demand a temperature within lesser tolerance. Someone has to decide the actual need, which is going to affect the process. If a consensus is not reached then, many a times unnecessarily expensive equipment and methods are used. It is worth to note that the user decides the process, tolerances etc. and this has nothing to do, in some cases, with the internationally accepted norms. Whatever affects the process, must be standardized and checked. Even an ordinary measuring scale should be checked, if it controls the result of the process.

Many times, it is not possible to get the calibration work done from an outside agency for a variety of reasons. For example, instruments, pressure gauges, weighing balances, mechanical tools and gauges etc cannot be made available out of work place for a long time and especially if it involves transportation. Some work can be carried out at locations itself but within limitations. So, having own laboratory certainly has advantages. The decision to have this laboratory or not is based on calibration program, expenditure involved, and financial gains by running it. Some questions when responded will give the appropriate solution.

- Do we manufacture and market good quality product?
- How do we decide the quality of our product?
- Contractual quality [specified by customers] and non- contractual quality [in house quality or built in quality] are good?
- Would more accurate equipment and caliberation practice give still better product and customer satiafaction?
- Are we satisfied by the work done by the external agency?

If answer to the last question is yes, it is worthwhile to check again if the laboratory meets the stringent requirements. But if it is decided to have own laboratory, there are some important needs to be fulfilled such as Laboratory management, Technical expertise, Selection of equipment, Documentation and Infrastructure.

Infrastructure entirely depends on needs. A clean environment, easily accessible location for all concerned should be selected. The room should preferably be on ground floor and free from shocks and vibrations, especially from heavy machinery. Electrical noise from arc or induction furnaces and transformers must be avoided.

All worktables should be ergonomically designed. Lighting which does not generate excessive heat and electromagnetic interference should be used. Air-conditioning should consider humidity control also. Air filtration, positive pressures if possible and low temperature gradients are desirable.

Equipment is procured depending on the actual measurement needs. All must have traceability to some accepted standards. The equipment should have an accuracy of about ten times better than the need. The selection needs very thorough involvement of all technical persons within the organization. It is better to wait than make haste in placing order.

The management of a laboratory and the equipment means the following:

- Measurement and check assurance program
- Schedule for calibration checks and record keeping
- Maintenance of traceability and standards
- Calibration methods documentation
- Withdrawal of equipment when necessary
- Calibration adjustments
- Feedback and training to all concerned and storage of data

Some points to ponder could be: measurement parameters, accuracy required, possible utility, special features or requirements, storage conditions, expertise available in the organization. It is better to buy from a reputed source at a higher price with a contract for at least two-three year service. Consider MTBF [mean time between failures or simply how many times failure is possible] as well as MTBR [mean time between repairs or how much time is required for repairs]. What is the ease of operations and controls? Is it user friendly? In some, the range could be large but the span could be made smaller for very accurate and best performance. Manuals will have to be kept for use and periodic checks for each device. All these considerations would be useful even for general procurements.

The validity of certification depends on the actual use. A vernier, which is used several times a day, may have a validity of only six months, after which it must be rechecked. This will depend on its wear and tear. But a kilowatt-hour meter of continuous use may have, due to its lesser deviation in use, a valid certificate of three years. The external certifying agency has no control or say in this. Even their validation may be amended in some case by documenting a statement that the equipment is not used so many times. If the calibration checks can be carried out over the working or useful range of a device say pressure gauge, then full range calibration check is not necessary. In some cases, extrapolation of reading is permitted. If you, the user, understand what is required for your needs and if you can substantiate this, all is acceptable. Look around in other organizations and solutions will be visibly suggested. The checks are for you and you alone are the master.

When you can measure what you are speaking about and express it in numbers, you know something about it. But when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be beginning of knowledge but you have scaresely in your thought advanced to the stage of science.

.... Lord Kelvin, British Physicist 1891

ALUMINIUM FURNACES

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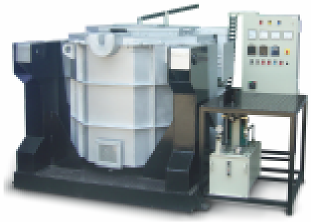
Electrical Furnaces


Stationary Furnace


Inner View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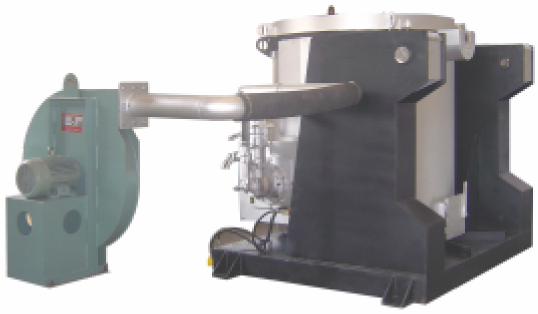
Manual Tilting Furnace


Hydraulic Tilting Furnace

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Density Index Unit


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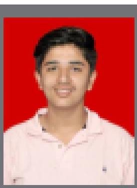
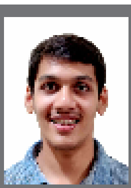

Varun Muthiyan


Om Bhandari

Effect of modification on mechanical and microstructural properties of Al-Si-Cu alloys.

Varun Muthiyan (3rd Year Metallurgy, GP Pune)
Om Bhandari (3rd Year Metallurgy, GP Pune)
Guide :- Mrs. N. S. Kadam (H.O.D. Metallurgy Dept., GP Pune)

Introduction

Aluminium alloys have a wide range of applications in the automotive and aerospace industries due to an excellent combination of castability and mechanical properties, as well as good corrosion resistance and wear resistivity. Additions of alloying elements such as Si, Cu and Mg improve the mechanical properties and make the alloy responsive to heat treatment.

To achieve satisfactory mechanical properties, microstructural modifications need to be done with the help of modifiers like Sr & Ti.

Theory

During the manufacturing of aluminium alloy castings important processes are carried out such as modification and degassing processes.

The microstructure of the Al-Si-Cu cast alloys primarily consists of a primary phase (α-Al) and eutectic mixture of Al-Si and intermetallic compounds of copper like $CuAl_2$, $Al_5Mg_8Cu_{26}$, Cu_2FeAl_7, $Al_5Cu_2Mg_8Si_6$. [1]

In order to increase strength of aluminium silicon based die cast alloys, 3 wt% Cu is introduced in Aluminium silicon alloy. Copper forms an intermetallic phase with aluminium which precipitates during solidification as blocky $CuAl_2$ or as alternating lamellae of α-Al + $CuAl_2$.

The $CuAl_2$ phase is blocky shape which is finely dispersed in α-Al and $CuAl_2$. particles within inter-dendritic region due to modification during solidification. High cooling rates can result in fine $CuAl_2$ particles.

Effect of copper on properties :-

With increasing copper content hardness increases but the strength and ductility exhibits different behaviour. During solidification, copper in solid solution is evenly distributed in spherodial particles, maximal strength can be achieved. This is due to modification and degassing.

Copper phase is present as a continuous network at the grain boundaries, it has little enhancement on strength but a significant decrease in ductility but can be enhanced due to modification and degassing. The copper containing Al alloys has low corrosion resistance because copper can disperse in aluminium oxide film and prevent passivation.

Our study

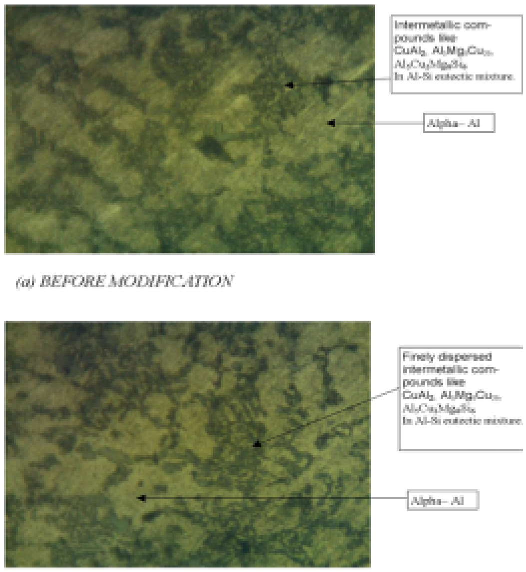
The analyses of the unmodified and modified AlSi8Cu3 hypo-eutectic alloys reported in this paper were conducted by tensile strength tests on the UTM and microscopic study.

The AlSi8Cu3 alloys were melted in an electric furnace in a graphite crucible; The modification with master alloys of strontium and titanium were added for the modification and further degassing was carried out with N_2 subsequently AlSi8Cu3 was cast in metallic molds to form the required test specimens.

On these test specimens further tests were carried out for the analysis of the same.
Composition according to spectrometer :-

Alloying elements	AlSi8Cu3 comp. Required	Composition observed
Si	7.5 – 9.5	9.180
Fe	0- 0.8	0.778
Cu	2.0 – 3.5	2.431
Mg	0.05 -0.55	0.201
Mn	0.15 -0.65	0.267
Ti	0.0 -0.35	0.061
Zn	0.0 -1.2	0.277
Ni	0.0 -0.35	0.061
Pb	0.0 -0.25	0.054
Sn	0.0 -0.15	0.004
Cr	-	0.0320
Al	Balance	

Microstructure :-



(a) BEFORE MODIFICATION

(b) AFTER MODIFICATION

Microstructures observed at magnification of 400X and using 3% Hydroflouric Acid as etching reagent

Properties :-

Tensile strength comparison between before modification and degassing and after modification and degassing:-

PARAMETERS	UNIT	OBSERVED	
		BEFORE	AFTER
DIA	(mm)	12.3	12.3
AREA	(mm^2)	118.87	118.87
GAUGE LENGTH	(mm)	50	50
YIELD LOAD	(KN)	23.5	26
ULTIMATE LOAD	(KN)	24	27
FINAL LENGTH	(mm)	51.8	53
PROOF STRESS (0.2%)	(N/mm2)	197.69	218.73
U.T.S.	(N/mm2)	201.9	227.14
ELONGATION	(%)	3.6	6

Conclusion :

Thus we can conclude that by modification and degassing process better mechanical and structural properties can be obtained such as ductility, elongation, UTS.

Reference :-

[1]https://www.google.com/url?sa=t&source=web&rct=j&url=https://bura.brunel.ac.uk/bitstream/2438/12874/1/FulltextThesis.pdf&ved=2ahUKEwiw2p_a1fPmAhW0yDgGHRavC_MQFjADegQICRAB&usg=AOvVaw2c8UoW_YIOwdAPx49JcVLG

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Journal. We look forward to more such articles from Engineers of future.

.... Editorial Board

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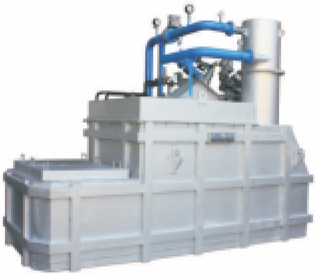
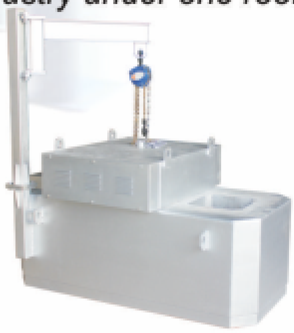


Melting Cum Holding

Electrical Holding (Crucible)



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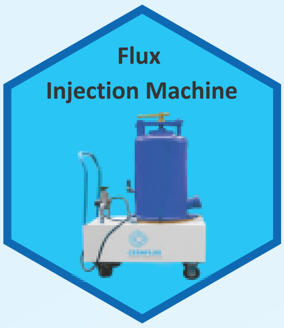

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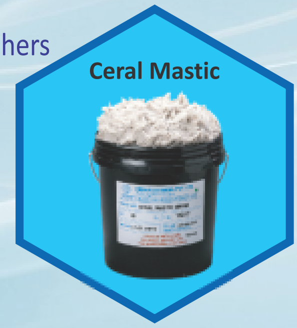

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Industry News

Paranjape Autocast Awarded National CSR Award in recognition of their work in 45 Anganwadis (Preprimary) of Khandala Taluka in Satara District, Maharashtra for 1000 children.

Mr. P. N. Paranjape, Chairman & Managing Director and Mrs. Neha Paranjpe, Director HR of Panrajpe Autocast received the award from Hon'ble President of India Shri Ram Nath Kovind in presence of Hon'ble Finanace Minister, Gover of India at a recently held function.

Paranjape Autocast is an industry member of IIF.

WHEELS INDIA TO SET UP CAST ALUMINIUM WHEEL PLANT NEAR CHENNAI

Wheels India Limited announced setting up of a cast aluminium wheel plant, with a manufacturing capacity of 7.5 lakh wheels per annum at Thevoy Kandigai, near Chennai, with an investment of INR 140 crores.
The plant was expected to start operations next year. The plant would have a manufacturing capacity of 7.5 lakh wheels per annum and would be ramped up in a phased manner.
Wheels India is the manufacturer of steel wheels for light vehicles, commercial vehicles, agricultural tractors, construction and mining equipment; air suspension systems for buses and trucks; and components and structures for windmill, railways and thermal power plants.

The company exports more than 20% of its sales and has a diversified base of over 40 customers.

Coffee talk

5th February 2020 (Wed)

Speaker

Dr. Bharati Dole.
Academician and Management and IPR consultant

Subject

Introduction to Intellectual Property Rights with specific reference to Patents

Coffee Talk

Feedback from Members

It was a very good programme. Speaker gave the insights to the subject with a very common examples which one could understand very well. Very Useful. Her subject knowledge was fantastic.

International Women's Day

GDC Tech Forum celebrated International Women's Day on 08th March,2020 . This was our 4th Year in a row. GDC Tech Forum has set objective of felicitating women engineers associated with GDC Industries.
There were about 11 participants from various companies.

- Ms. Sarita R. Sonawane, AURANGABAD ELECTRICALS LTD.,
- Ms. Jungare Snehal Madhukar, AURANGABAD ELECTRICALS LTD.,
- Ms. Kavita S. Mathe, AURANGABAD ELECTRICALS LTD.,
- Ms. Anuradha Kulkarni, ENDURANCE TECHNOLOGIES LIMITED
- Ms. Monika More, ENDURANCE TECHNOLOGIES LIMITED
- Ms. Priya Chandrakant Fule, MINDA CORPORATION LTD.
- Ms. Snehal Balasaheb Dongare, MINDA CORPORATION LTD.
- Ms. Mayuri Sunil Aher, MINDA CORPORATION LTD.
- Ms. Pallavi Suresh Madane, SIGMA ELECTRIC MANUFACTURING CORPORATION PVT.LTD.
- Ms. Rohini Shivaji Landge, SIGMA ELECTRIC MANUFACTURING CORPORATION PVT.LTD.
- Ms. Kiran Sahebrao Ghagare, SIGMA ELECTRIC MANUFACTURING CORPORATION PVT.LTD.

This event was graced by young entrepreneur Ms. Ankita Shroff, Shroff Group, as a chief guest.

Mr. Anil Kulkarni- Vice Chairman of GDC Tech Forum, welcomed chief guest .
After welcome address of Mr. Kulkarni, Mr. B. P. Poddar Chairman Coffee Talk Committee introduced all participants were introduced to audience. Each participant shared their professional journey, ups and downs , difficulties faced during education. Each ones journey was inspiring and motivating , learning for audience.

Finally chief guest Ms. Ankita Shroff, addressed participants and gathering on her professional journey which was amazing. Chief Guest felicitate participants and women present in audience. Mr. RT Kulkarni felicitated Chief guest and thus event ended.

We are sure audience got immensely benefited, motivated through this event.

GDC Tech Forum will continue this event and many more such events which will bring awareness among forum members.

Upcoming Webinars in July - Sept 2020

For Aluminium Foundry & Related Industries.

A. Multiple Sessions Programmes

1. Defect Analysis & Remedial Measures
   - Problems Solving Techniques
   - Defect Identification and Remedial Measures
   - Case studies
   - Process Control

2. Metallurgy of Aluminium Alloys
   - Effect of Alloying Elements & Phase Diagrams
   - Heat Treatment of Aluminium Alloys

3. Methoding of Aluminium Gravity Die Casting
   - Die Design Basics & Construction
   - Modulus Calculations with Examples
   - Gating System basics with some calculations

B. Single session programmes

- Costing
- Cost Reduction
- Die Coats and Lubricants
- OEE

For Further Details Please Contact :-

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Congratulations...........

Dr. Rajesh Chaudhari, Vishwakarma Institute of Technology, Pune for securing patent on " A METHOD FOR THE PREPARATION OF Ti-TiB IN SITU COMPOSITE".

A novel method for titanium composite was developed to enhance strength, stiffness and wear resistance of components for aerospace and biomedical implants. Most inexpensive precursor was used to form titanium boride whiskers in titanium matrix by in - situ reaction process by spark plasma sintering technique.

This research work was completed by him at IIT, Madras, Chennai.

Statistical Techniques for Industry

Pramod Gajare – Consultant. Email: pramodgajare2013@gmail.com

25. Specific cases in context of process, Part IV

Learning Objectives:

- Situation where the standard control charts are not convenient
- Concept and method for High-Low control chart
- Key features of High- Low control chart
- Understanding the concepts through practical example

Situation where standard control charts are not convenient

In this chapter we are going to discuss one more situation where the standard control charts are not convenient. This situation is precision machining; which is generally linked with tool wear. The typical examples of precision machining are turning, grinding, honing etc. for;

- the sealing applications as in piston and cylinder for the pumps
- interference fits as in the bearing and the shaft

As we had seen earlier, the characteristics of process dominated by tool wear are;

- The mean chart shows increasing or decreasing trend. This trend would continue till the tool is reset or replaced. Over the time the mean chart shows a typical saw tooth pattern.
- The distribution for saw tooth curve is the uniform or rectangular distribution. This non-normal distribution does not follow the rules of normality such as Cp or Cpk calculations or the Shewhart rules for control chart evaluation.
- The mean has no real value in controlling the process, since it is governed by the rate of tool wear. Due to economical reasons, the mean is allowed to drift, within the control limits. As such the calculations for index Cpk is not applicable in such cases. One has to calculate the index Cp only.

In case of precision machining the variation within the subgroup is practically close to zero and the between the subgroups variation is mainly due to the tool wear. Whatever variation is observed within a subgroup, mainly it consists of the measurement error.

Discussion on measurement errors

Since the variation is very less in precision machining as compared to the medium grade machining, it is important to capture this variation carefully without any errors.

When measuring a diameter, if the measurement is taken only one particular location the inherent roundness error (difference between the largest and the smallest diameter) is normally ignored.

At some times multiple measurements are taken which captures this roundness error, but then the readings are averaged out. This averaging hides the important information about the variation present for that particular diameter.

Figure 25.01 shows an illustration for measurement errors. One sample consists of measurements on five consecutive parts for a diameter.

- When the diameters are measured only at one place on the parts, the observations are 10.004, 1.006, 10.004, 10.008 and 10.007 mm, giving the range of 0.004 mm as a within subgroup variation.
- When the maximum and minimum diameters are measured on each of the five parts, the variation in maximum diameters is 0.001 mm and 0.002 mm for the minimum diameters. Here the variation within the parts i.e. roundness error for the diameters detected as 0.003mm to 0.004 mm. **This roundness error was missed out when the measurements were taken only at one place on the part.**
- On the other hand, when the maximum and minimum observations on each part were averaged out, the outcome for average diameters is 10.0055, 10.0060, 10.0050, 10.0060, and 10.0065 mm.

This gives a value of range as only 0.0015mm, which is misleading due to averaging effect.

From above example the role of precise measurement can be understood clearly.
The $X_{High-Low}$ control chart is a useful tool for capturing the maximum possible information on process variation. This chart is generally used with the range chart.

Concept and construction of High-Low Control Charts
While using the High-Low control chart, only one part is measured at a time.

- The centerline of the $X_{High-Low}$ chart is normally at the target value i.e. mid-point of the tolerance band. One can place the centerline at the previously established process average.
- The control limits (UCL and LCL) are drawn equispaced around the centerline. The distance between the control limits is generally taken as 60% of the tolerance band.
- The specification limits (USL and LSL) are also plotted on the $X_{High-Low}$ chart for better guidance.
- The maximum and minimum observations are taken on the individual part and results are recorded. The sample size is n = 1.
- The measurement is continued as the production goes on.
- The maximum and minimum points are plotted for each sample. Thus each sample is represented by two points on the $X_{High-Low}$ chart.
- All the maximum points are connected with a straight line, and similarly all the minimum points are connected with a straight line.
- The range chart is constructed by Shewhart method and observations are plotted.

Selection of control limits
As seen earlier, when the process is dominated by tool wear, the distribution is uniform which is non-normal. Hence rules of normal distribution are not applicable in such cases. As such the control limits can not be calculated as X bar +/- A2 Rbar. There is different method for calculating the control limits.

Since this process is dominated by tool wear; the characteristic value is constantly changing due to effect of tool wear, till the tool is reset or replaced. Considering this, the value of control limits depends on our decision about at what value of the characteristic the tool has to be set and after tool wear at what value of characteristic the tool is to be reset or to be replaced. In other words, how much portion of tolerance band is to be utilized is governed by this decision. Hence this decision forms the control limits.

We had seen earlier that, the capability index Cp is defined as ratio of tolerance band and the spread of the process. It is expressed in the equation below.

Cp = Tolerance band / Process spread
.... Eq.: 25.01

Hence for achieving a particular level of capability index, the control limit band will be of value 'a' multiplied the tolerance band, equally placed around the mean or target value. Here 'a' is a constant.

So the equation 25.01, gets modified as,
Cp = Tolerance band / a (Tolerance band)
This can be further simplified as
Cp = (USL-LSL) / a (USL – LSL) .... Eq.: 25.02

From equation 25.02, we can have typical values of "a" as 0.75, 0.60, and 0.50. The respective calculations are shown below.
Cp = 1.33 = (USL-LSL) / 0.75 (USL – LSL)
Cp = 1.66 = (USL-LSL) / 0.60 (USL – LSL)
Cp = 2.00= (USL-LSL) / 0.50 (USL – LSL)

In other words,
For achieving capability index Cp = 1.33, the control limits should be 0.75 times the tolerance band.

For achieving capability index Cp = 1.66, the control limits should be 0.60 times the tolerance band.

For achieving capability index Cp = 2.00, the control limits should be 0.50 times the tolerance band.

It is important to mention that just by selecting the control limits at the desired level, one can not achieve the expected value of capability index. Selection of correct cutting parameters and the tool wear rate are the major governing factors to achieve the capability.

Comparison of normal distribution and uniform distribution will help to understand the method for selection of control limits.

This comparison is illustrated in Figure 25.02. One process which is not dominated by tool wear is shown in black colour. The variation in this process follows normal distribution. Periodic observations were taken with subgroup size n = 4. The specification is 19.10 +/- 0.030 mm.

Following are results of calculations.

- Process Mean (X bar) = 19.101 mm
- The standard deviation σ = 0.0075 mm. (Calculated with R bar / d2 method.)
- The control limits for mean chart calculated as X bar +/- A2 Rbar are as follows.
    - UCL = 19.112 mm
    - LCL = 19.089 mm
- Total spread of process 6σ = 0.045 mm.
- Process capability index Cp = 1.33.

Now let us consider a precision machining process with the same specifications. The target for process capability index Cp is same as that of the earlier process i.e. Cp = 1.33 is the target.

This second process is superimposed in Figure 25.02 with blue colour.

Following are the values of control limits;

- Upper control Limit UCL = 19.123 mm
- Lower control Limit LCL = 19.078 mm

Here the control limit band is 0.045 mm (19.123 - 19.078). This band is 0.75 times the tolerance band of 0.060 mm, as the target is Cp = 1.33.

We can see that the control limit band of 0.023 mm for a process with normal distribution is quite close as compared to the control limit band of 0.045 mm for precision machining process. This is because the normal distribution is denser in the center and thinner on the tail ends. On the other hand throughout the uniform distribution, the density is of same amount.

Method of use for the High-Low charts

- Set the process at lower control limit (LCL) for outer diameter and at upper control limit (UCL) for the inner diameter. In case machine warm-up is a known assignable cause, then set the machine at the target value.

- Take observations periodically and plot maximum and minimum observations on the $X_{\text{High-Low}}$ chart. Similarly plot the range for each sample on the range chart.

- In case of outer diameter when the upper control limit is crossed, the process needs to be adjusted. The tool needs to be reset.

- In case of inner diameter when lower control limit is crossed, the process needs to be adjusted. The tool needs to be reset.

- For any given sample, the difference between the maximum point and the minimum point indicates the variation within that part i.e. the roundness error for that part. This variation can be seen on the $X_{\text{High-Low}}$ chart as well as on the range chart very easily.

- If the difference between the maximum point and the minimum point increases, it is an indication of increase in roundness error, which is result of excessive wear of the tool. The cutting edges of the tool are losing the required sharpness and geometry. When the value of range crosses upper control . limit on the range chart the tool needs to be replaced.

- When both the maximum and minimum points show sudden shift, it is an indication of presence of some assignable cause, like change in raw material batch. Stop the process and identify the cause. In most of the cases, the tool needs to be reset.

- The trend in "wrong" direction indicates presence of some assignable cause, Stop the process; identify and eliminate the cause.

Example of sudden shift is shown in Figure 25.05. At observation #12, there is a sudden shift in the value of X. The operator failed to identify this shift; hence the two observations (#12 and #13) are below the Lower control limit.

Figure 25.06 illustrates the case of trend in wrong direction. After observation #17, the tool was changed and from observation #18 onwards the trend in wrong direction is observed till observation #21. Something went wrong during tool change. After identification of assignable cause and elimination of the same the increasing trend continues from observation #22 to observation #25.

Key features of High-Low Control Chart

- These charts are very simple since only two observations are involved for each sample.
- Calculations are simple. Only difference between the Maximum value and minimum value is to be calculated.
- The warning signals are very clear and distinct. It is very easy to understand, when to adjust the tool and when to replace the tool.
- The tool wear rate can be easily understood with the help of these charts.
- These charts also can be used for controlling geometrical features such as taper on the diameter, parallelism for a linear dimension etc...
- Sufficiently precise instrument is required so as to capture the variation correctly.
- If the customer is not sensitive to the roundness error the High-Low charts are not recommended.

Illustrative Example

For outer diameter 10.00 +/- 0.02 mm from the previous data, the capability index Cp is 1.33 and the average variation Rbar is 0.0035 mm. Subsequent to this, the data collected periodically is shown in Table 25.01. The relevant actions taken during the production are also shown in the last column of this table. The $X_{High-Low}$ chart and the range chart plotted are shown in Figure 25.03 and Figure 25.04. In the $X_{High-Low}$ chart, the target 10.00 mm is shown by a black line. The upper control limit and the lower control limit (UCL and LCL) are represented by red lines. For better understanding the upper and lower specification limits (USL and LSL) are also drawn and these are shown by black lines.

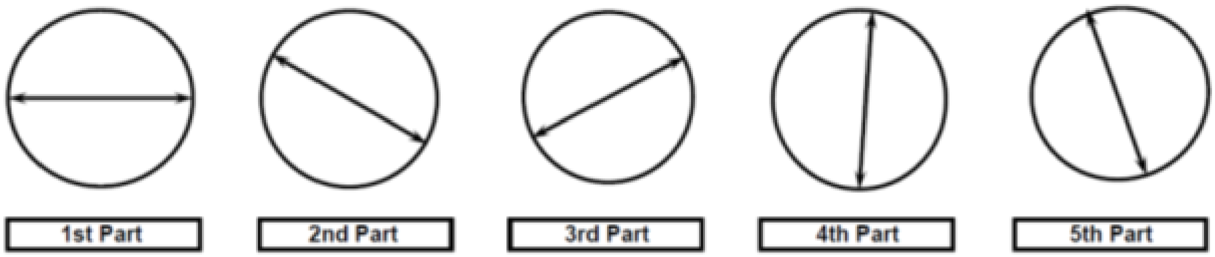
specification limits (USL and LSL) are also drawn and these are shown by black lines.

- The process is initially set at the target value. The machine warm-up may be a known assignable cause in this case.
- As the production continues the $X_{High-Low}$ chart shows increasing trend towards the upper specification limit. The sixth observation of 10.014 and 10.010mm is very close to the upper control limit. Hence at this time, the tool is adjusted by 0.020mm.
- Since the next observation after the tool adjustment is 9.992 and 9.989 mm is above the lower control limit, there is no need for further adjustment. Also there is no need for measuring second sample. The process is left to continue on its own.
- For the first 14 observations the roundness error (Range) is between 0.003 mm to 0.006 mm. All these observations are within the control limit of the range chart. An increasing trend of a small value is also seen on the range chart.
- The fifteen observation shows roundness error of 0.008 mm. Even though this is within the control limit of the range chart; it is an early warning that the tool is wearing fast.
- For the next observation (#16) the roundness error has increased to 0.012 mm, which is beyond the upper control limit of 0.0114 mm for the range chart. The upper control limit of 10.015 mm on the $X_{High-Low}$ chart is also crossed. The tool is changed after this observation. The operator has taken the correct decision of changing the tool since the range is high.
- After the tool change the immediate next part is measured. The observation (#17) is 10.017 and 10.014 mm, which is beyond the UCL of the $X_{High-Low}$ chart. Hence the tool is adjusted by 0.010 mm.
- After the adjustment, the next observation (#18) is 10.007 and 10.003 mm. Although this observation is within the control limits, it is not nearer to the lower control limit. Hence for taking maximum advantage of tool wear trend and making the process economical further adjustment of 0.020 mm is done.
- The observation #19 after the second adjustment is 9.990 and 9.987 mm. This observation is close to the lower control limit. Hence the process is left to continue on its own.

- After the tool change, the roundness error observed between 0.003 to 0.005 mm. All these observations are within the control limit of the range chart.
- From first observation till the last observation (#25), no wrong trend (decreasing trend instead of the increasing trend) is observed.

What we learned?

- Measuring a diameter only at one place ignores the important information of roundness error on that diameter. Also measuring maximum and minimum diameters and averaging out the results hides the variation due to roundness error.
- For $X_{High-Low}$ chart only one sample is measured at a time. The highest and lowest values observed on the same part are plotted. Similarly for the range chart only the difference between the highest value and lowest value on the same part is plotted.
- The control limits for $X_{High-Low}$ chart are based on the target value of capability index Cp.
- The control limits for Range chart are based on the average range obtained from previously measured data.
- When any point on $X_{High-Low}$ chart crosses the control limit, the process is out of control. The tool needs to be adjusted.
- When any point on range chart exceeds the control limit, this increase in range is indication of tool being worn out. The tool needs to be replaced.
- For the $X_{High-Low}$ charts the run tests as applied for standard control charts are not applicable.
- The $X_{High-Low}$ charts are not recommended when the customer is not sensitive to the roundness error.



Measurement at only one place	10.004 mm	10.006 mm	10.004 mm	10.008 mm	10.007 mm
Max. dia.	10.007 mm	10.008 mm	10.007 mm	10.008 mm	10.008 mm
Min. dia.	10.004 mm	10.004 mm	10.003 mm	10.004 mm	10.005 mm
Roundness	0.003 mm	0.004 mm	0.004 mm	0.004 mm	0.003 mm
Average dia.	10.0055 mm	10.0060 mm	10.0050 mm	10.0060 mm	10.0065 mm

Figure 25.01: Illustration for measurement errors

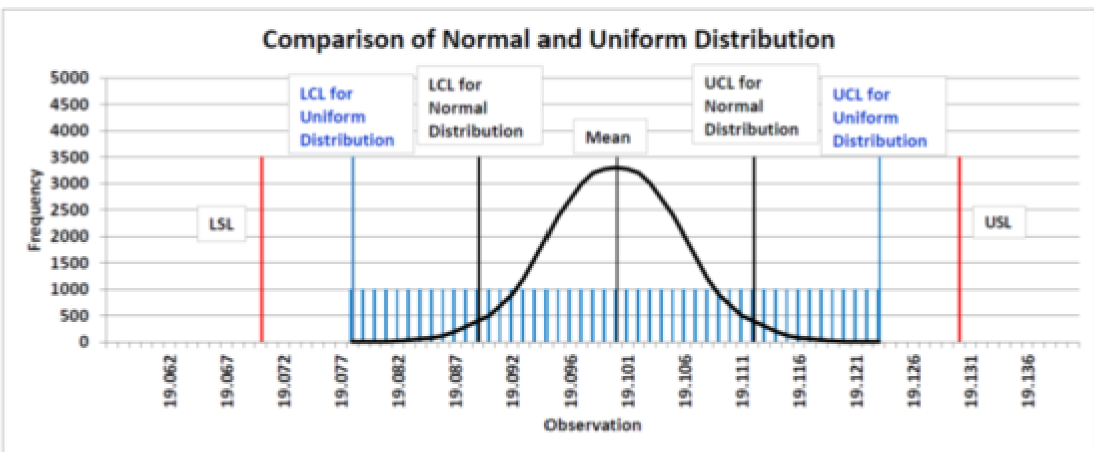


Figure 25.02: Comparison of Normal and Uniform Distribution

Sample No.	High	Low	Actions taken
1	10.001	9.998	
2	10.006	10.002	
3	10.007	10.004	
4	10.010	10.005	
5	10.012	10.009	
6	10.014	10.010	Tool adjusted 0.020 mn
7	9.992	9.989	
8	9.992	9.988	
9	9.996	9.991	
10	9.997	9.993	
11	9.999	9.994	
12	10.005	10.001	
13	10.006	10.000	
14	10.009	10.004	
15	10.013	10.005	
16	10.016	10.004	Tool Changed
17	10.017	10.014	Tool adjusted 0.010 mn
18	10.007	10.003	Tool adjusted 0.020 mn
19	9.990	9.987	
20	9.992	9.988	
21	9.996	9.993	
22	9.998	9.994	
23	10.000	9.997	
24	10.005	10.001	
25	10.007	10.002	

Table 25.01: Data set for diameter 10.00 +/- 0.02 mm

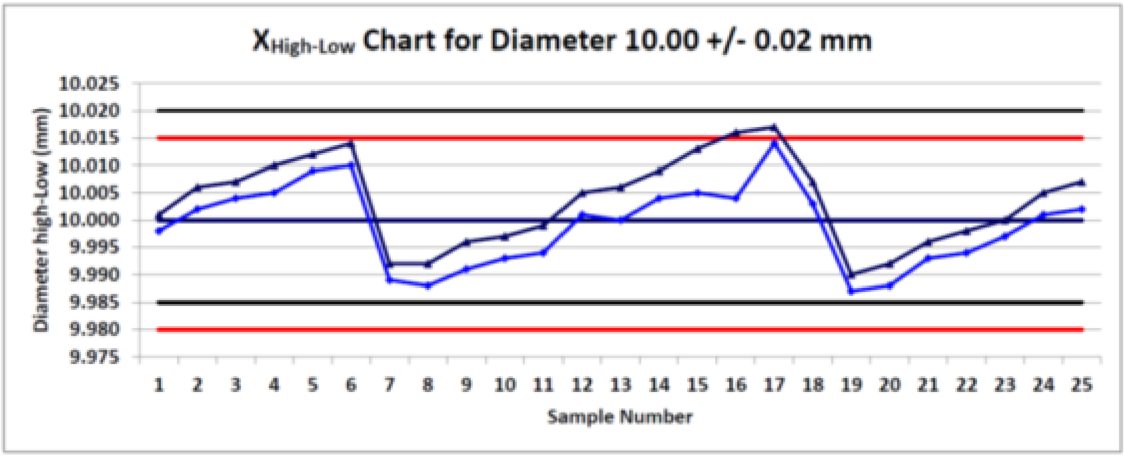


Figure 25.03: X $_{High-Low}$ chart for diameter 10.00 +/- 0.02 mm

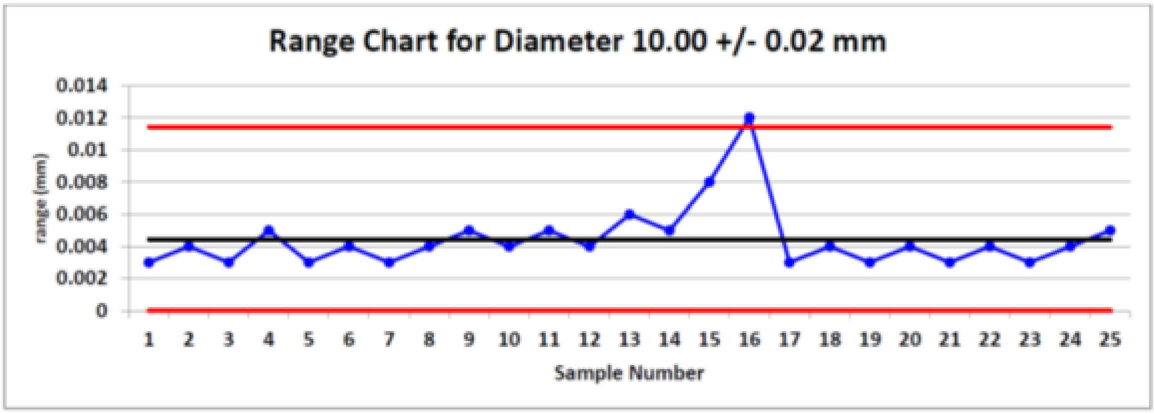


Figure 25.04: Range chart for diameter 10.00 +/- 0.02 mm

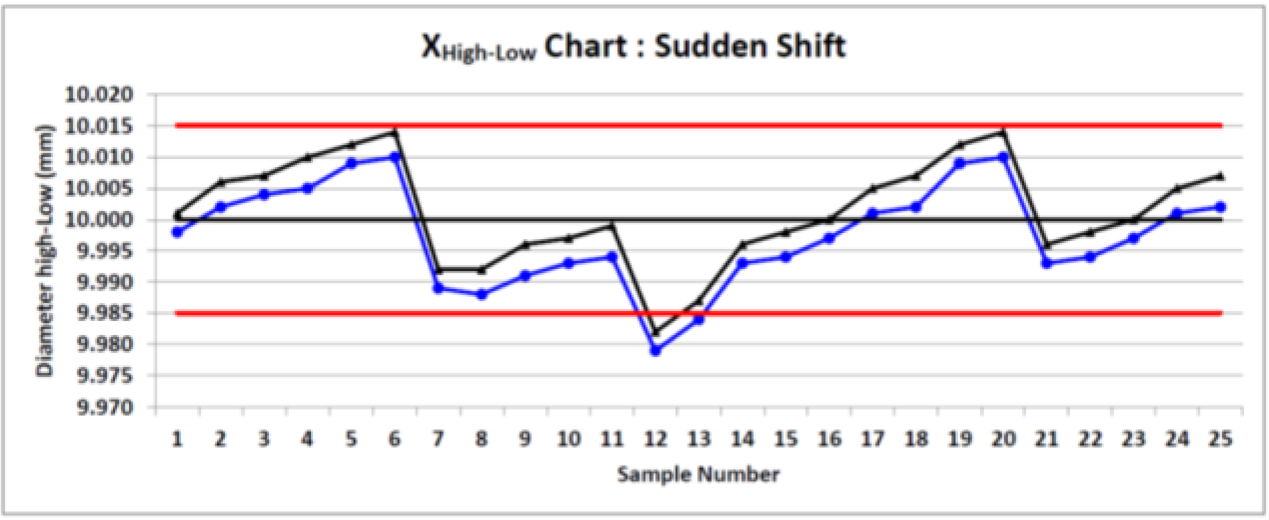


Figure 25.05: Example of "Sudden Shift" in $X_{\text{High-Low}}$ chart

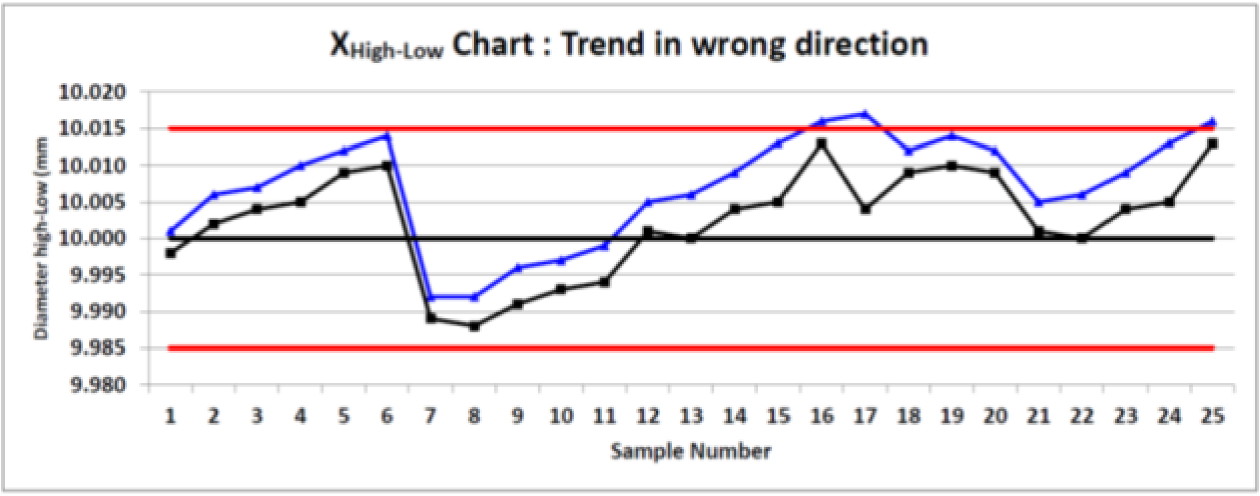


Figure 25.06: Example of "Trend in Wrong direction" in $X_{\text{High-Low}}$ chart

Acknowledgements

- I would like to acknowledge my Guru Mr. S B Deo,who taught me 'Statistical Process Control'.

SHRADHANJALI

Mr. Sharad Prakash

His Dedication & Love for
Foundry Industry will always be
remembered by GDCTECH FORUM Member

Training Programme

GDCTECH along with DAA Consulting Mumbai organised ONE DAY PROGRAMME ON "GLOBAL TRADE AWARENESS FOR BUSINESS HEADS" on 16th February 2020 at Hotel President.

The programme was well attended with 16 delegates from 13 organisations. The faculties are from DAA Consulting. Mr. Ravi Bharathwaj, who is a Harvard University Post Graduate presented on Forex Optimisation. Mr. S K Srinath & Vikas Prajapathi presented on Maharashtra & Tamilnadu State Industrial Policy and also Customs Bonded Warehousing Scheme.

Following topics covered:

- Changing Tax Environment and International Trade Landscape
- WTO Dispute and it's possible Effect
- Free Trade Agreements & it's impact on Global Supply Chain
- Forex Optimisation through AI
- E – Invoicing under GST
- Maharashtra & Tamil Nadu Industrial Policy
- The New Customs Bonded Warehousing Scheme
- Expectations out of the new Foreign Trade Policy

The delegates express satisfaction about the contents of the programme and good interaction.

Trainers' Training

Achwal Industries on 1 st March 2020 Discussion with for casting problems.

Solution Centre

Trainers' Training Programme Oragnised On 1st March 2020 & Mr. Vishwas Kale Conducted the Programme by giving valuable inputs to the Faculties which can help in improving the quality of training programmes.

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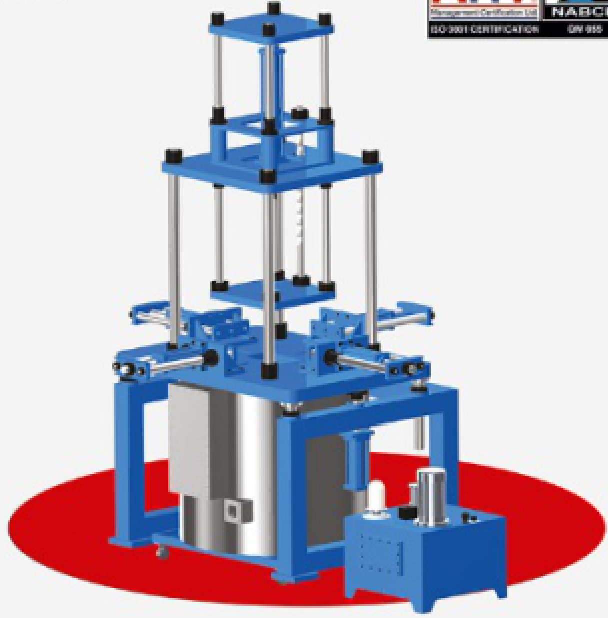

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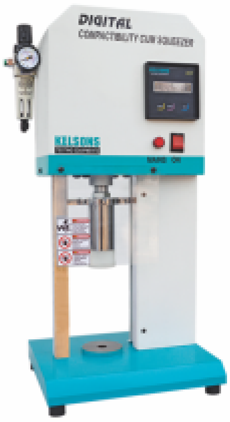

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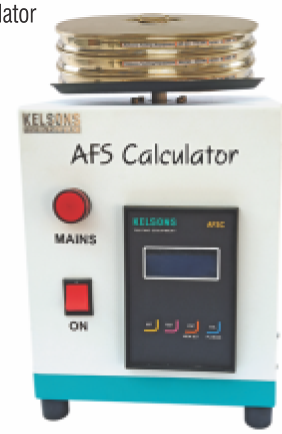

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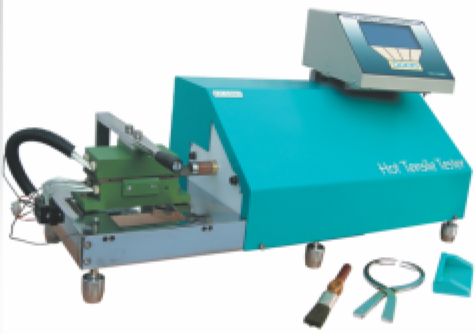

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