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Chapter News Letter



EDITORIAL . . . ✍

Dear Readers,



Season's Greetings and Happy New Year 2018!

I am happy to bring you this First News Letter in the New Year. 'Change is the only constant thing' - inline with this philosophy, we have brought some changes in the

chapter News Letter. I am sure you will like this new format. Your views are welcome.

M&MT is an Iconic conference series of our ASM Pune Chapter. As a part of Silver Jubilee Celebrations, we organised M&MT 2017 focused on Automotive Dies, a topic very close to all of us, still fairly untouched in such conferences. You will find detailed report and glimpses of M&MT 2017 in this newsletter.

To continue the tradition of being the First, Pune chapter also hosted First Dr APJ Abdul Kalam Award Memorial Lecture. Dr Pratyush Kumar of Boeing, delivered the lecture in COEP. You will be proud to know, 'Teach the Teachers Camp' was first time held in India, as usual, Pune Chapter hosted this.

You will be excited to read coverage on the Grand Gala evening to celebrate Silver Jubilee of the Chapter.

In our column, Women Metallurgist Speaks, the First Woman Metallurgist of COEP, Ms. Nalini Nene, Director Metafore Labs Kolhapur, shares her experience with all of us.

I am happy to inform you, that one of the strongest Pillars of Pune Chapter Dr Prabhakar Renavikar was conferred FASM. He received the award in MS&T 2017.

Induction Hardening is one of the most popular Heat treatments in the Industry. Valery Rudnev discusses several recently developed innovative processes and apparatus as well as expectations from future technology in the technical article 'The day after tomorrow - future of Induction hardening'.

India has strong heritage for Metallurgy, an article by Dipti Singh will let you know the efforts taken to conserve Cannons across the forts in Maharashtra.

We welcome your comments on this newsletter and suggestions to improve this further.

Udayan Pathak
Editor

Dr. Prabhakar Renavikar was conferred FASM



ASM International established the honor of Fellow of ASM (FASM) in 1969 to provide recognition to ASM members for their distinguished contributions to materials science and engineering.

Recipients of one of the highest honors in the field of materials, ASM Fellows are technical and professional leaders who have been recognized by their colleagues and now serve as advisors to the society.

Silver Jubilee Celebration of ASM Pune Chapter

ASM International Pune Chapter Celebrated Silver Jubilee Grand Gala Nite on 9th Nov 2017. Dr. Kamachi Mudali - Chairman and Chief Executive, Heavy Water Board, Department of Atomic Energy, Government of India was the Chief Guest. Dr. T S Sudarshan, Trustee ASM International, was Key Note Speaker.

Dr. H M Mehta, distinguished member of ASM International, who brought ASM India, Dr. Pradip Goyal past trustee of ASM International, Premkumar Aurora, Trustee ASM International, Mr. Mahesh Shinde, Chairman, Institute of Mechanical Engineers western Region and office bearers from different chapters were present as special dignitaries. Program started with chapter chairman Mr B R Galgali welcoming Chief Guest Dr. Kamachi Mudali and Dr T S Sudarshan. Subhsah Kulkarni, Chapter Vice Chairman, welcomed Premkumar Aurora. Mr. K C Gogte welcomed Dr. A K Tiwari. Dr. Dr.

Prabhakar Renavikar welcomed H M Mehta. Dr. Pradeep Goyal was welcomed by Mr. Hemant Zaveri.

Mr. B R Galgali narrated journey of Pune Chapter from Lean Chapter formed in 1997 to one of the most vibrant chapters in the world in 2017. He also presented Vision and Mission of Pune Chapter.

Founder Members of ASM Pune Chapter were also present to grace the function. Past Office Bearers were felicitated, with Silver Jubilee Memento. Silver Jubilee Cake was cut by Founder office bearers.

The celebration concluded with Cocktails and Dinner.

Few Photos are included in this news letter and more photos are displayed on the link below.

<https://photos.app.goo.gl/J0r1rqllKPPNIGv92>



Dr. Prabhakar Renavikar was conferred FASM



Their solicited guidance, provided by ASM Fellows to the ASM Board of Trustees, enhances the society's standing as a leading organization for materials and provides a unique resource to serve the worldwide community of materials scientists and engineers in the years ahead.

One of the most deserving Indian Candidates for FASM is Dr. Prabhakar Renavikar. ASM acknowledged this and FASM is conferred to Dr. Prabhakar Renavikar.

"For long term vision and dynamic leadership in the development and implementation of

alternate materials for automotive vehicles and in the promotion of ASM International activities in India."

Dr. Renavikar, personally received this during MS&T 2017.

Glimpses of Silver Jubilee Celebration



MATERIALS & MANUFACTURING TECHNOLOGY 2017

ASM International Pune Chapter in its Silver Jubilee year, conducted an International Conference and a Concurrent Exhibition on Materials and Manufacturing Technology, with a focus on Automotive Dies, on the 9th and 10th of November 2017 at Hotel Orchid, Pune. A total of 90 delegates participated in the Conference. There were 16 papers presented in these 2 days by renowned Indian and International Speakers.

9. Plastic die moulding – a new outlook by Dr.S.Mould Portugal.
10. Modelling of die wear - by Dr.Imre Feld.
11. Present and future of manufacturing technologies for body side dies by Dr..David Peres and team.
12. Fluidized bed nitro carburizing to improve performance of hot die steels by Mr.Valmik Bhavar and team.

On the occasion of the 25th year, ASM International Pune Chapter launched a souvenir illustrating the passage of the 25 years. The souvenir also carried messages from renowned personalities in the ASM movement and well-wishers. It also featured column interviews from many of the members and well-wishers of ASM Pune Chapter. A separate section was devoted to technical data. The exhibition though small because of the space constraint was well received. Many visitors came specially for the exhibition. These included young students, who came in groups from different colleges in Pune and over 200 of them had their first exposure to materials and were mostly drawn from the discipline of mechanical engineering.



Delegates attending the Conference

Dies are extensively used in all major automotive manufacturing processes, such as, stampings, forgings, die castings, injection moulding, forming, etc. In recent years, many developments have taken place in die materials, die designs, heat treatment, manufacturing technology, surface modification, faster development of automotive components, and service and repairs of dies. Use of high strength steel for light weighting and cost reduction, reducing the product life cycle cost, are some of the challenges faced by the industry today. Hence, the following topics were selected for the Conference.

The topics covered were :

1. Observations on plasma nitriding tools and dies by Dr.Zoltan Kolozsvary of Romania.
2. Sheet metal stamping dies life cycle by Mr.Pravin Grover.
3. Dies design and production of near net shape thin blades ducted propeller by new rheocasting process for naval application by Mr.V.M.Nimbalkar and team.
4. Life prediction of L6 steel using strain-life curve considering strain softening phenomenon by means of low cycle fatigue testing by Mr.Sanket Inamdar.
5. PDC die repair using linear cladding process by Dr. Gururaj Telasang and Mr.G.Padmanabhan.
6. 3D printing of dies by Dr.Sundar Atre.
7. Innovative heat treatment of PM parts to build dies by Mr.Srini Raghavan.
8. Challenges and opportunities in hot forming die manufacturing by Mr.Sachin Nirgurdkar.

13. Hybrid Additive Manufacturing – Conformal Cooling Channel for PDC Tools by Dr.Gururaj Telasang.
14. Improving numerical results in sheet metal forming through advanced material and tribological modelization by Dr.Eneko Saenz De Argandona and team.
15. Cryogenic treatment and new generation coatings of dies by Mr.Bojan Bodogornish.
16. Shot peening – simple and cost solution to increase die life by Mr.Amit Aradhya.



Ms. Ruta Barve of Cummins chairing the first session.

There was a question and answer session after every talk. The response to the talks could be gauged by the questions put up by the delegates.

In the end of the 2 day session, there was a panel discussion with Mr. Sanjeev Gaur-Tata Motors, Mr.Avinash Khare-IMTMA, Dr.David Peres, Mr.Manish Khandelwal and Mr.K.C.Gogate. The speakers gave their views in their own sphere of specialization and every speaker had something unique to share from their practical experiences with the delegates.



Students who came to see the exhibition

For the Silver Jubilee celebrations, Dr.Kamachi Mudali-Chairman and Chief Executive, Heavy Water Board, Department of Atomic Energy, Government of India was the Chief Guest. Dr.T.S.Sudarshan delivered a technical talk on “Emulate to Innovate”, Dr.Sudarshan in his talk gave simple examples of how nature can be adopted for the development of new products and new technologies. Some of the examples were to emulate the shark skin for developing high quality urinary catheters and stents and how we have and we could adapt certain features from animals, fish and birds for agility and survivability and specific examples like frogs for skin texture, dolphins for their sonar sensing and numerous other species like octopus, fish etc to create engineering products of significant value with the ability to degrade without contamination.

Dr.Mudali in his address gave very compelling examples of how metallurgy was in existence since early times in India. He specifically spoke about the Ashoka Pillar in Delhi, which was erected 1400 years ago and stands in the open weathering the environment without the formation of rust. He was fortunate enough to do research on the Pillar and shared some of his findings with the audience. He also gave examples of development of brass and bronze castings in South India over seven to eight centuries ago.

More photos are displayed on the link below.

Day 1: <https://photos.app.goo.gl/J0r1rqILKPPNIGv92>

Day 2: <https://photos.app.goo.gl/SwFeLDG3een4Dtl1>



M&MT 2018 : A Grand Success



M&MT 2018 : A Grand Success



They formatted News Letter



Avinash Modak is Associate in Knowledge Center of ERC, Tata Motors Limited. He designed revised Master page and Headers and Footers. Avinash is very creative and completed Post Graduation in Library Science. Avinash also designed Silver Jubilee Logo, Banners and Standees for ASM International Pune Chapter as a Volunteer.



Pratik Ranpura is expert at Coreldraw and PageMaker. He designed many News Letters and brochures of various conferences for ASM International Pune Chapter.

Materials Advances Supports “UDAN” – Dr Pratyush Kumar 1st Dr. A.P.J. Abdul Kalam Memorial Award Lecture



Aerospace Materials. He also explained challenges and opportunities for Aerospace Materials Industry with the background of emerging 3D Printing technique. He talked about emerging employment opportunities, skill sets required in aerospace industry due to 'Make in India' mission. Pratyush Kumar also addressed various queries from the audience.

Dr. Pratyush Kumar delivered lecture in New Auditorium of COEP. All India awards instituted by ASM International India National Council were distributed to the awardees. Awards were given at the hands of Dr Pradeep Goyal, Dr KamachiMudali, Prof B B Ahuja and Prem Aurora. The awardees are

“Light Weight Aircrafts consumes less fuel, which reduces the operating cost of air service. This light weighting of aircraft was possible through development of high performance advanced materials like Aluminum, Titanium, Metallic and Polymeric Composites. Due to this less operating cost is possible to charge less fare. This is how Materials Advances support Hon. PM Shri Narendra Modi's mission UDAN – Ude Deshka Aam Naagarik” Said Dr Pratyush Kumar, President Boeing India and Vice President Boeing International USA. He was delivering First Dr APJ Abdul Kalam Award Memorial Lecture instituted by ASM International India National Council hosted by ASM International Pune Chapter jointly with College of Engineering Pune (COEP). Pratyush Kumar in his award lecture elaborated journey of Aerospace Materials Development starting from Cloth and Wood used in first Aircraft until today's Advanced

STUDENTS AWARD

POST GRADUATION

- ◆ Ms Semanti Mukhopadhyay
IIT Kanpur
Guide: Dr. Krishanu Biswas
- ◆ Ms Hem Shruti Bhardwaj
IIT Bombay
Guide: Dr. Amartya Mukhopadhyay
- ◆ D. Sankar Rao
IIT Bombay
Guide: Dr. S. Parida

DOCTORAL RESEARCH

- ◆ S. Balakrishnan
IIT Chennai
Guide: Dr. K.C. Harikumar ,
Guide: Dr.K. Ananthasivan
- ◆ Ms. Ambreen Nisar
IIT Kanpur
Guide: Dr.Kantesh Balani
- ◆ Ms. Vaibhavi Sonetha
IIT Bombay
Guide: Dr.Jayesh Bellare



Semanti Mukhopadhyay



Hem Shruti Bhardwaj



Abreen Nisar



Vaibhavi Sonetha

INDUSTRY AWARDS

1. M/s Metal Power Analytical (I) Pvt. Ltd., Mumbai
2. M/s Solar Technocats Pvt. Ltd, Rajkot
3. N.D. Gupta Enterprises, Pune
4. Metatech Industries, Pune

Committee lead by Dr Satyam Sahay, finalised Students Awards while, Dr Ashok Tiwari lead Industry Awards committee.

Prof B B Ahuja, welcomed Dr Pratyush Kumar and Guest of Honour Dr KamachiMudali, while Udayan Pathak proposed vote of thanks and conducted the program. ■



D Sankar Rao receiving Award at the hands of Dr Pradeep Goyal & Dr Kamachi Mudali



S Balakrishnan receiving Award at the hands of Prof B B Ahuja



Industry Awards : Brijesh Pipaliya of Solar Technocast Pvt Ltd receiving Award at the hands of Dr Pradeep Goyal



Mr Priyadarshan Pant of Metal Power Analytical (I) Pvt Ltd Mumbai, receiving Award at the hands of Dr Kamachi Mudali



Mahesh Thite of Metatech Industries Pune Receiving Award at the hands of Prof B B Ahuja



Rahul Gupta receiving Award at the hands of Mr Prem Aurora

Glimpses of 1st APJ Abdul Kalam Memorial Award Lecture



TEACH THE TEACHER CAMP

ASM International Pune Chapter, Automotive Research Association of India (ARAI), Pune and ASM India Council, jointly conducted a Teach the Teacher Camp at ARAI, Pune on the 7th and 8th November 2017. The theme of the Camp was Challenges and Opportunities in Materials Engineering for Teachers from Polytechnic and Engineering Colleges. On the first day of the Camp, the focus was on Industrial Practices and Success Stories. Forty five teachers attended the camp and over 85% of them were drawn from mechanical, civil and electrical engineering fields.

The topics covered were :

1. Introduction to the Camp by Mr. B. R. Galgali and Mr. Rahul Gupta.
2. Non-destructive testing by Mr. Sudhir Phansalkar.
3. Heat treatment and advances in processes by Mr. S.G. Kulkarni.
4. Materials testing by Mr. Thakur Desai and Mr. Kulkarni.
5. Casting technology – present, future and opportunities by Mr. V.K. Purohit.

On the second day of the Camp, the focus was on Advances in Materials and Future in



Participants – Teach the Teacher Camp

Materials Engineering.

The topics were :

1. Engineering innovations through materials engineering by Dr. T.S. Sudarshan.
2. 3D printing by Dr. Sundar Atre.



Dr.T.S. Sudarshan giving his presentation

3. Plasma nitro carburizing and advancements in the processes by Dr. Zoltan Kolozsvary.
4. Modelling technologies for materials engineering and its role to meet future challenges by Dr. Imre Felde.

The Camp was highly interactive on both the days with lot of fundamental discussions among the Teacher Delegates and the Speakers. The

Teachers appreciated the training and remarked that this training process has opened up the thinking process and will further motivate them to do research work. A clear message was given that they will further circulate these learnings and opportunities to their students and motivate them to opt for materials engineering as their career options.

At the end, there was a panel discussion with ARAI Director – Ms. Rashmi Urdhwareshe, Dr. K. C. Vora, Dr. T. S. Sudarshan, Mr. B. R. Galgali and Dr. Zoltan Kolozsvary.

It was agreed to formulate a group of the speakers and the teacher delegates so as to take these activities and discussions ahead and continue this activity under Pune chapter once or twice a year.



**TWO
DAYS
WORKSHOP
ON**



PRACTICAL FAILURE ANALYSIS & CASE STUDIES



- ▶ 22 & 23 Jan 2018
- ▶ HOTEL PRIDE, UNIVERSITY ROAD, SHIVAJI NAGAR, PUNE

By

Ms Debbie Aliya

Analytical Inc. Aliya USA





ABOUT THE WORKSHOP

Participants will learn the basic damage categories, and methods to distinguish fatigue fracture from overload, determine what type of loading(axial, bending, torsion, shear)caused the conditions that allowed fracture. A criteria for evaluating safety factors based on the crack appearance will be presented for fatigue. The importance of understanding how to recognize brittle and ductile features at macro and microscales will also be presented.

AGENDA OF THE WORKSHOP

- Steps in a complete and “quick” failure analysis: When to do each
- The Failure Analysis Toolbox: Eyes, Brain, Mind, Microscopes, Mechanical tests, Etc.
- Damage Categories : Deformation, Wear, Fracture, Corrosion
- Basic Macro-Fractography
- Special techniques to overcome some of the limitations usually encountered when evaluating dirty, damaged fractures and brittle materials.
- “Traditional” surface appearances linked with fatigue and overload
- Basic Simplified Loading Geometries and their associated fragment shapes
- Special considerations for case hardened steels

WHO SHOULD ATTEND

- Design Engineers
- Materials and Metallurgy Engineers Personnel performing failure analysis
- Quality and Reliability Engineers
- Students and budding researchers

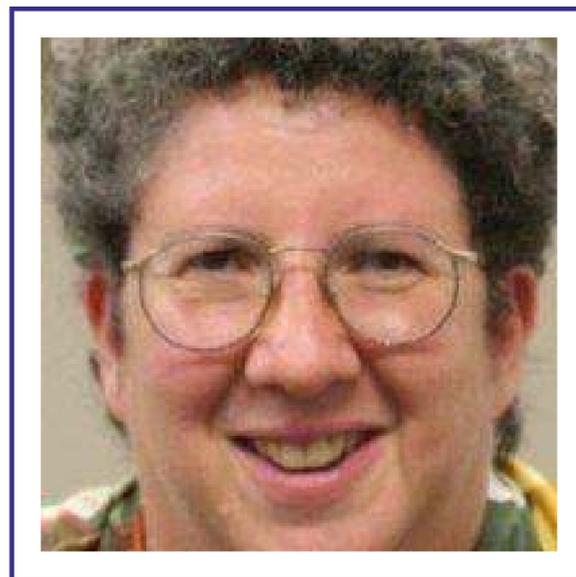
WHAT THE PARTICIPANTS WILL TAKEAWAY

1. A basic working knowledge of how to use visual examination to determine the damage category of a “failed

part” or assembly, and the limitations of visual analysis.

2. The most emphasis with focus on fracture, macro-Fractography and loading geometry.
 3. Highlights on a spectrum of tools used in failure analysis work on manufactured components
- How to perform a visual examination of a damaged assembly or component
 - How to classify damage, in the service of failure prevention (deformation, fracture, wear, corrosion, complex, thermal degradation)
 - How to recognize if unanticipated loads or environmental conditions contributed to the demise of the component
 - How to tell if the component was loaded in a manner not according to design.

ABOUT THE FACULTY



- Debbie Aliya is the owner of Aliya Analytical, Inc., USA, which specializes in failure analysis and prevention. What makes her approach unique is the attention to the insights of philosophy and psychology in engineering.
- Debbie has a BS in Metallurgy and Materials Science from Carnegie-Mellon University (Pittsburgh,PA) and an MSin Materials Science and Engineering from North-western University (Evanston,IL). She has served several times as Chair of the

ASM International Failure Analysis Committee, and contributed several articles and participated in the editorial duties for the 2002 Metals Handbook volume on Failure Analysis. She also has a few articles in the 2004 edition of Volume 9 on Metallography.

- She has wide ranging interests, and has presented on Thinking Skill Optimization at various ASM International, Society of Manufacturing Engineers, Society of Automotive Engineers, and Machinery Failure Prevention Technology Society events. She has also taught multiple classes on Failure Analysis and Prevention, including a special topics class for graduate Materials Engineering students at Western Michigan University. She is currently the chair of the Education Committee of the new ASM Affiliate Failure Analysis Society. She has also written a science fiction novel which promotes the cultivation of clear thinking.

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High Resolution (8 Mb) and Low Resolution (2.2 Mb) file of this News letter is available on request.



Conserving heritage: Neglected, cannons across forts in state to be mapped, preserved

“Cannons are testimony to the knowledge of engineering in medieval India, and hence need to be studied closely,” said Tejas Garge, the newly appointed director of the Maharashtra Directorate of Archaeology and Museum, at the fourth annual workshop of explorations in Maharashtra held at the Mumbai university’s Kalina campus Saturday.

Garge gave a presentation on the “pathetic condition” of cannons across the state and the urgent need to study and preserve them. During the presentation, 'Gunnery in Deccan: An Archaeological perspective', Garge pointed out that cannons across forts in the state lay in a state of complete neglect.

The Indian Express had reported on December 16, 2015 about a 60-kg cannon that went missing from the Padmadurga Fort in Raigad district. Garge, however, said that geomapping and preservation of the cannons had already begun, and people could expect them to be displayed better next time they visit a fort in the state. Data related to cannons, their typography and geographical positions at Padmadurg, Murud-Janjira, Korlai Fort, Revdanda and Daulatabadhas already been compiled. he said.

“We will make better frames to display the cannons, instead of the cement platforms they are currently kept on,” Garge added. Talking



about the typography and engineering of these cannons and guns, Garge said locally made cannons during the Maratha rule were often not of very superior quality. “Many cannons found in the forts of Daulatabad, MurudJanjira, Padmadurg, Korlai etc. have British and Dutch emblems or marks, showing they were imported by the Marathas,” said Garge. Meanwhile, Pune-based archeological researcher Sachin Joshi, who has mapped 235 cannons made and acquired in the 17th century (1674 to 1680), has been preparing a dossier since 2015.

The study by Joshi, a researcher from the archeological department of the Deccan College Post-Graduate and Research Institute, along with Dr P P Deshpande from department of metallurgy and material science at Government College of Engineering, Pune (CoEP), involves not only mapping and counting of these cannons, but compiling detailed metallurgical and technical analysis

reports on them.

Joshi and Deshpande began the documentation and analysis of the cannons six years ago, a project that was funded by the Indian National Science Academy, New Delhi, and the University Grants Commission (UGC).

They are now creating 2D drawings and 3D models of the cannons that were studied. According to Joshi, during his research, he found that out of the original 30, only 18 cannons remain in the Rasalgarh fort. He said: “Sadly, just six out of the total 25 cannons are left at the Sinhagad fort while 65 out of the total 200 remain in Janjira fort.”



Dipti Singh is Journalist with Indian Express Mumbai. She writes on Education and Policy issues. dipti.singh@expressindia.com

Women Metallurgist Speaks

1. What is your Engineering background ?

I am a graduate in Metallurgical Engineering from College of Engineering Pune in the year 1966. I was the first Lady Metallurgist to graduate from Pune University. After graduation I took Foundry as my career. I started with M/S.Yashwant Iron and Steel Works Ltd. Kolhapur as Trainee and rose to the position of Foundry Manager. I worked with them for more than 25 years during which period I was responsible for developing many heavy and intricate castings. In 1993, I resigned from the job and started consultancy firm Nucleus Foundry Services. I offer consultancy in the area of melting, metallurgy, sand Systems, methoding, Rejection Analysis and control for cast iron and S.G.Iron Foundries. I started Metafore Synthesis ,a Metallurgical Testing Laboratory in the year 1997. Our services include wet Analysis of Ferrous and Non Ferrous metals, Testing of Foundry raw materials, Tensile and Microstructure testing etc.

2. What attracted you to engineering ?

In my School days I loved physics, Chemistry and Mathematics which are fundamentals for Engineering. I had a passion for doing unusual and uncommon things. In those days very few girls were opting for Engineering This also acted as driving force for taking up Engineering Field as career.



Ms. Nalini Nene is first Women Metallurgist of the College Of Engineering Pune. She runs Metafore Chemical & Metallurgical Testing Laboratory in Kolhapur. She also offers consultancy for Foundry. She is reachable on metaforec19@gmail.com .

3. What part of your job do you like most ?

When somebody asks for thorough testing in an effort to solve their problem, I like to help him. I also love Trouble Shooting Part Of Consultancy to Foundry Industry.

4. What are Your professional achievement ?

I have written four Marathi Books on various aspects of foundry Technology. I have done pioneering work on design of Divided Blast Cupola and contributed to popularization of the design in Maharashtra and other states.

I am a recipient of following awards

- i) Packo Puraskar for Services to foundry Industry – By Packo Power Trust Kolhapur year 1994.

- ii) Gunavant Abhiyanta Puraskar from Lions Club Solapur year 2011
- iii) Best Engineer award by Institution of Engineers Kolhapur Local Centre year 2014
- iv) Udyogshree Puraskar by Kolhapur Engineering Association year 2017

5. How many people do you work with ?

In Metafore I work with a team of four. When I go out for consultancy in foundries, I have to work with a team of workers and Engineers.

6. What are your hobbies ?

Reading, Writing, Music (vocal and instrumental), Treking

Latest Books Read.

Diwali Magazines and Translated book “Mee Malala” by Supriya Vakil. The book is a story of Malala Yusufjai and her fight against Talibanis for her right to education.

7. What message would you like to share with newcomers particularly females in metallurgy/ Foundry Field

First and foremost thing is you should have thorough liking for the field. Never underestimate yourself. Never ask for any concessions or favours. There is no substitute for hard work. Prove yourself and nobody can stop you from reaching the top.

The day after tomorrow – the future of induction heating by Valery Rudnev

Today's metal working and heat treating shops must quickly adjust to a rapidly changing business environment, maximizing process flexibility and energy efficiency, yet still satisfy continuously increasing demands for higher-quality products. This article addresses these and other challenges faced by modern industry when applying induction systems for heating and heat treating. Several recently developed innovative processes and apparatus are reviewed and expectations for future technological developments are provided. This article is based on a keynote lecture presented at XVIII International UIE-Congress "Electrotechnologies for Material Processing" in Hannover, Germany, on June 6–9, 2017.

It is always difficult to try to predict what to expect the day after tomorrow. There have been many people who have tried to predict the future and failed, though there are a few of Nostradamus caliber. A quote from Lord Kelvin, a brilliant scientist, who once said, "Radio has no future," should serve as a precaution for those who are not as gifted as he. Nevertheless, let's imagine what the near future holds for induction heating based on recent technological advancements and what items of an induction "wish list" could reasonably soon become a reality.

Heating by means of electromagnetic induction is a topic of major significance, and the technology continues to grow at an accelerated rate. Thermal applications include hardening, tempering, stress relieving, normalizing, brazing, soldering, coating, drying, as well as preheating ferrous and nonferrous metallic and composite materials prior to warm and hot working and many other processes [1]. Heating inductor and induction coil are terms used interchangeably for the electrical apparatus that provides the electromagnetic heating effect in the workpiece positioned in close proximity. An inductor is often simply called by induction professionals as a "coil", but its geometry does not always resemble the classic circular coil shape. As an example, Fig. 1 shows an array of a virtually endless variety of geometries of heating inductors needed to accommodate a correspondent endless variety of parts (Fig. 2). Certain know-how is



Fig. 2: Variety of workpiece geometries that routinely apply induction heating (Courtesy of Inductoheat Inc.)

associated with almost each application applying different coil/part geometry introducing certain challenges to so called conventional induction designs.

COMMONLY OVERLOOKED METALLURGICAL SUBTLETY OF INDUCTION HARDENING

Induction hardening is commonly described as a process that involves the heating of the entire component or its portion to the austenitizing temperature, holding it, if necessary, for a period long enough to obtain required degree of austenite homogenization and then rapidly

typical heat intensities for selected induction applications.

Metallurgically inclined professionals are aware that rapid heating affects the kinetics of austenite formation, shifting it toward higher temperatures in order to create conditions conducive to the required diffusion-based processes and producing an austenitic structure with a sufficiently uniform distribution of carbon.

If an austenite has appreciably non-uniform distribution of carbon then, upon quenching, a decomposition of heterogeneous austenite begins in lower carbon regions. This shifts the

CCT curves to the "left" with greater probability of forming upper transformation products. The CCT curves for regions having excessive amounts of carbon will be shifted in the opposite direction with a corresponding reduction of the MS temperatures. Thus, heterogeneous nature of austenite might result in an

Application	Heat intensities, °C/s
From room temperature to A_{c3} temperature range	
Contour hardening of small and medium-size gears	300–1,800
Surface hardening of shaft-like components	150–800
Through hardening or deep case surface hardening	50–500
Normalizing of thin wires, ropes, rods, strips, etc.	250–400
Through heating prior to warm and hot working	2.0–60
From room temperature to temperatures below A_{c1} critical temperature	
Subcritical annealing of "thin" workpieces	50–350
Stress-relieving and high temperature (650 °C) tempering	20–60
Low-temperature tempering (300 °C) of medium size components	4.0–10

Table 1: Typical heat intensities in selected induction heating applications [1]

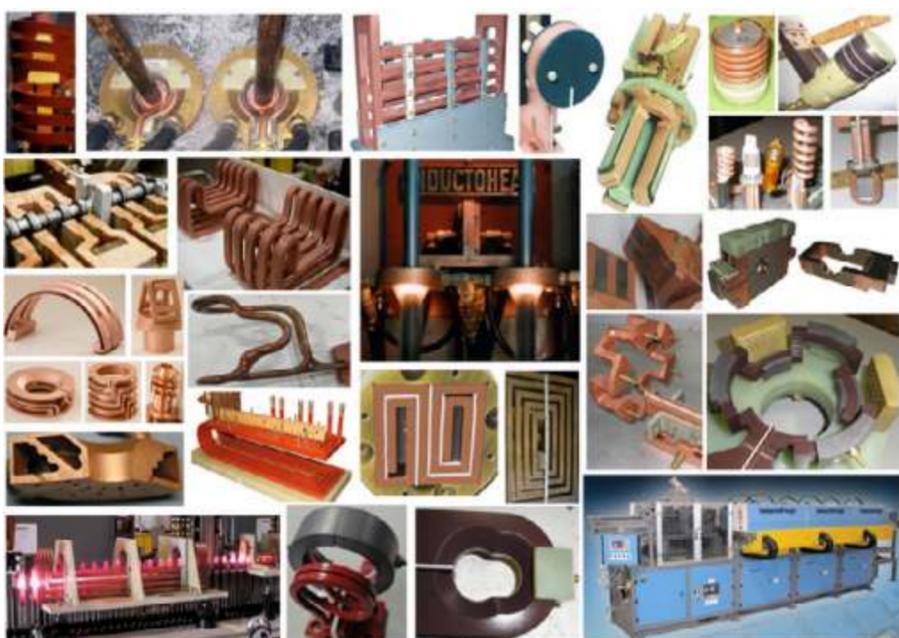


Fig. 1: An array of a virtually endless variety of geometries of heating inductors (Courtesy of Inductoheat Inc.)

cooling it to below the MS temperature where the martensitic transformation begins. At the same time, there are less frequent cases where instead of forming martensitic structures it might be desirable to form predominately bainitic or pearlitic structures or mixed structures.

In the case of hardening steels, the critical temperatures are often determined by mathematical correlations that indicate an effect of

unacceptable heterogeneous as-quenched microstructure. Observation of "ghost pearlite" and/or other upper transformation products during a metallographic evaluation of as-hardened specimens can be associated with the presence of severely heterogeneous austenite.

Presence of significant microstructural and chemical segregations in the prior (parent) microstructure could have a measurable impact on a degree of heterogeneity of formed austenite after rapid heating. A number of studies were conducted to quantify the impact of heat intensity rates and prior microstructure on a shift of critical temperatures producing continuous heating phase (CHT) transformation diagrams.

It is NOT widely known even among metallurgists that when heat intensities exceed about 20–30 °C/s, instead of the normal order of critical temperatures: Ac_1 , Ac_2 , Ac_3 , rapid



Fig. 3: An appearance of billet-sticking (left) and cracking (right) are often associated with subsurface overheating (middle) [1]

heating can switch an order to Ac2, Ac1, Ac3. On the basis of the information provided by Orlich et al. [2–3], there are many steels that exhibit such a behavior [2–3]. This change might be critical in some induction heating applications (including hardening, as well as subcritical and intercritical processing) leading to unexpected occurrence of severe eddy current cancellation and drastic efficiency reduction, which could shift a relatively easy job to an almost impossible one [1].

In contrast to thermal or mechanical properties, electromagnetic properties of metallic alloys are not readily available in the literature and it is our hope that "the day after tomorrow" will improve our knowledge in regards to those physical properties critical for an electromagnetic induction.

REAL-LIFE CHALLENGES ASSOCIATED WITH TEMPERATURE MEASUREMENT AND SYSTEM FLEXIBILITY

J. W. N. Sullivan, Science Writer (1886–1937), once said: "It is much easier to make measurements than to know exactly what are you measuring." Some practitioners involved in induction heating prior to hot working (e. g. forging) incorrectly assume that with induction bar/billet heating the coldest temperature is always located at the core of the billet and the maximum temperature is always located at its surface. It is also often assumed that overheating does not occur if surface temperature that is measured by a pyrometer does not exceed the maximum permissible level. It is imperative to recognize that under certain but very realistic conditions, the presence of heat losses from the workpiece's surface in combination with in-depth heat generation typical for induction heating may shift the temperature maximum further away from the surface marking its location somewhere beneath it.

An appearance of billet-sticking (Fig. 3, left) and cracking (right) are often associated with subsurface overheating. Fig. 3, middle reveals that severe overheating (localized melting) occurred below the surface. A billet-sticking/fusion problem is more likely to occur with conventional power distribution along the induction line when the system runs at a rate slower than the nominal for which it was designed. Since the system puts more energy into the workpiece in the beginning of the heating line, too much energy soaks down into the

subsurface area in cases when the line runs slowly. The presence of surface heat losses can reverse a commonly expected radial heat profile.

Case study [4]: An induction system for heating 0.064 m diameter carbon steel billets at a production rate of 2,500 kg/h is made up of three inline coils connected electrically in series and fed from a 1 kHz inverter (Fig. 4). Fig. 5 shows surface-to-core profiles at an exit of the last coil when heating 0.051 m diameter carbon steel billets: Fig. 5a – at a slower rate and Fig. 5b shows heat profiles when processing larger diameter billets at a nominal rate. Note that in both cases the surface temperature that would be recorded by

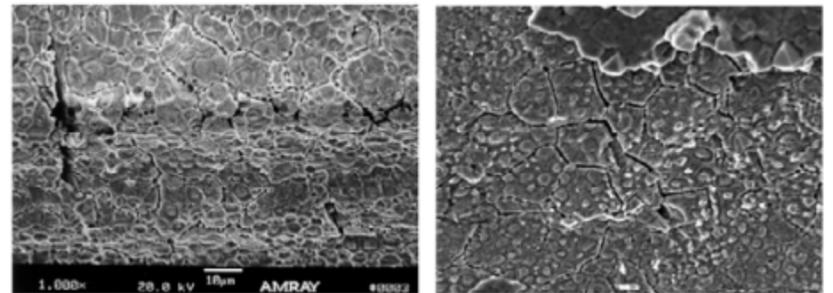


Fig. 7: Examples of grain boundary liquation (incipient melting) phenomenon [5]

power distribution along the heating line.

Since in production environment internal temperatures cannot be easily measured nor even seen, they can only be simulated mathematically. Therefore, accurate temperature monitoring based on a reliable projection of temperature distribution is imperative in designing modern induction heaters.

For a number of years, Inductoheat has included temperature profile modeling software iHaz in an equipment package of InductoForge systems (Fig. 6). This software does not just simulate electromagnetic-thermal processes, but it also takes into consideration topology of a particular style of power supply, it's load matching capabilities and bus networking. The software helps to generate the power settings for each inverter (in case of in-line systems), which can be downloaded into a PLC recipe and dynamically predicts the internal thermal conditions of heated workpieces.

In a modern, vibrant and globally-competitive market place, it is important not just to build a system that provides accurate heating but a system with superior process flexibility that allows quick adjustment to a rapidly changing business environment. Long-term customers may move their production on a moment's notice. The producers must be able to get new business to cover lost business. One way to maximize the flexibility of induction heaters, ensuring the highest heating quality and minimizing energy consumption is applying modular induction heating technology. There are several variations of the modular design. InductoForge modular induction heating system allows adjusting, not only a power distribution along the heating line but also frequency (500 Hz to 6 kHz range) to optimize heating and allowing intelligent redistribution of 3-D electromagnetic heat generation and energy consumption of each coil depending upon the production run [4].

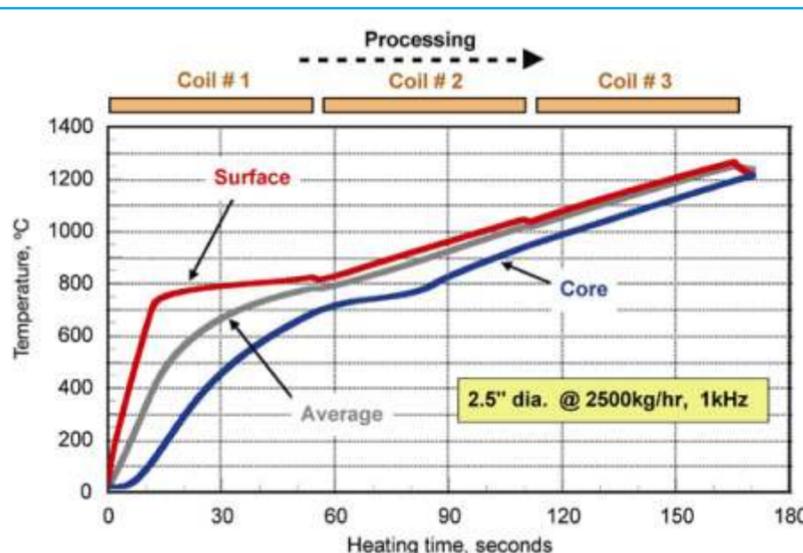


Fig. 4: Results of computer modeling of an induction system for heating 0.064-m-diameter carbon steel billets comprising three in-line coils. Frequency is 1 kHz [4]

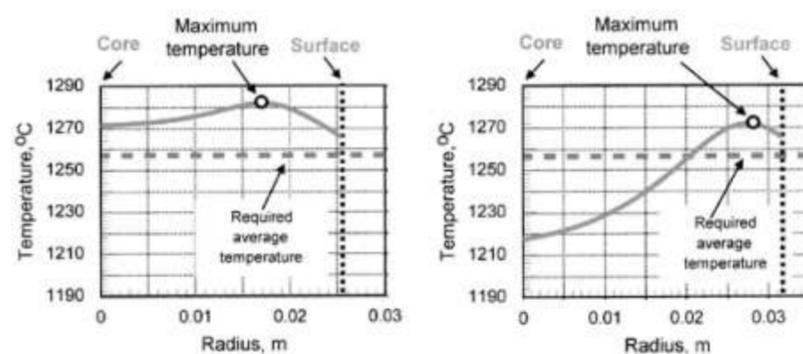


Fig. 5: Surface-to-core profiles at an exit of the last coil when heating 0.051 m diameter carbon steel billets: a – at a slower rate and b – shows heat profiles when processing larger diameter billets at a nominal rate [4]



Fig. 6: Temperature profile modeling software iHaz™ has been included in an equipment package of InductoForge™ systems (Courtesy of Inductoheat Inc.)



For example, if today's market situation requires heating larger billets (e. g. 115 mm diameter) then lower frequency (e. g. 500 Hz) produces a more in-depth heating effect and minimizes heat time, providing an improved radial temperature uniformity. If tomorrow the market situation changes, demanding heating of smaller size billets (e. g. 30 mm), then appropriate inverters can be reconfigured to be able to produce higher frequency (e. g. 6 kHz). This results in a more surface-like heating effect, avoiding eddy current cancellation, maximizing heating efficiency and minimizing energy consumption. Since each coil can be controlled individually, the power distribution along an entire heating line can be re-balanced and optimized for particular production run based on software recommendations. If the line is running fast, more power can be shifted to the cold end of the heating line. If the line is running slow, the maximum power can be distributed closer to the hot end of the line increasing the efficiency of the heater and improving thermal conditions [1, 4].

It is expected that "the day after tomorrow" highly specialized application-oriented software utilizing advanced

numerical simulation techniques will be an essential part of the package of induction machinery and ... it does not have to be finite element (FEM) codes. In many cases, a combination of different numerical methods (including finite difference, finite volumes, finite elements, edge elements, boundary elements and others) provides substantial advantages over using a single modelling technique.

INDUCTION HARDENING OF CAMSHAFTS WITH ALMOST UNDETECTABLE DISTORTION

The ability to produce low distortion components is critical necessity of modern technologies, which directly affects process cost-effectiveness and product quality. There are several factors that affect distortion of heat-treated components including workpiece geometry, material grade and its prior microstructure, hardness pattern etc. Camshafts have relatively complex geometry with a lack of symmetry. One of the critical factors affecting distortion is the amount of heat generation and an ability to form a uniform hardness layer regardless of irregular shape of the lobes. The greater the amount of heated metal, the larger and the uneven expansion will be causing greater distortion. Therefore, efforts should be made to minimize the amount of metal being heated while producing sufficient hardness case depth.

With conventional induction hardening, an attempt to provide a sufficient austenization of the heel region of the lobe and needed hardness depth often results in measurable overheating of its nose. This can promote some brittleness and sensitivity to intergranular cracking. An increased use of electric arc furnaces that utilize recycled scrap may produce steels, which may be rich in Cu or other low melting point residuals. Over the last decade, the amount of copper residual has increased in some commercial steel grades.

If during camshaft hardening, the nose of the lobe is overheated then besides other

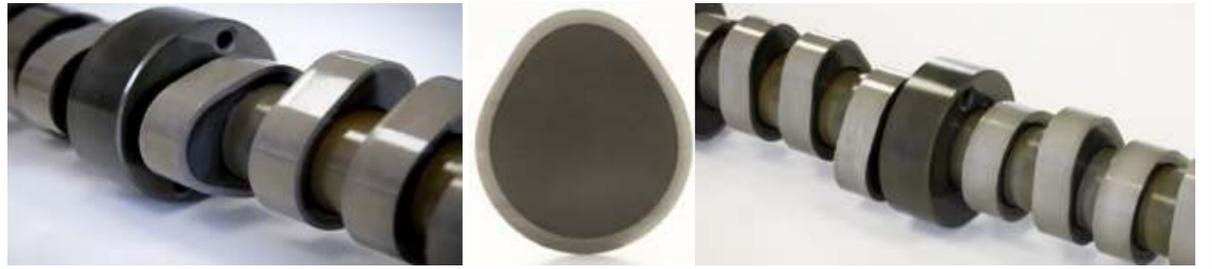


Fig. 8: Examples of true contour hardening patterns of camshaft lobes (Courtesy of Inductoheat Inc.)

unwanted metallurgical conditions, a phenomenon of grain boundary liquation (incipient melting) may occur (Fig. 7) [5]. This is the most common cause of cracking. The phenomenon of grain boundary liquation (GBL) can be amplified by preferential segregation of manganese, sulfur and some other elements at the austenitic grain boundaries. Both phosphorous and sulfur markedly affect the steel overheating. This lowers the melting point in the grain boundary region compared to the nominal solidus temperature of the steel leading to several undesirable phenomena during hardening and potentially promoting a temper embrittlement with locally increased Mn content. Undesirable combinations of impurities, residuals and trace elements used in the steel making, as well as non-metallic and intermetallic constituents could increase brittleness and crack sensitivity. Therefore, it is highly desirable to minimize peak temperatures during austenization.

Patented non-rotational technology developed for hardening of crankshafts (SHarP-C™) has been recently successfully expanded to surface hardening of camshafts. The compound benefits of SHarP-C™ Technology for heat treating camshafts can be summarized as follows:

- Achieving almost undetectable camshaft distortion (about 3–5 microns; based on 1.5 l and 2.0 l diesel or regular fuel engines) and, in many cases, an elimination of an entire straightening operation [6]. This is the combined result of three factors: (1) the ability to form a true uniform hardness pattern (Fig. 8) regardless of camshaft's topology, as well as geometry and orientation of the cam lobes, (2) reduction of localized peak temperatures during austenization (60–90 °C reduction on average) and (3) avoidance of applying any pressure/ forces during camshaft hardening.
- Experience of using SHarP-C™ camshaft hardening technology reveals producing not only superior straightness but also better metallurgical properties forming fine grain martensitic structures and minimizing a probability of crack development and grain boundary liquation due to a significant improvement in temperature uniformity along the cam lobe

perimeter.

- The energy consumption during both heating and cooling is reduced. Depending upon the specifics of the camshaft's geometry and heat treat specifications, combined savings on energy consumption may exceed 12–18 % compared to presently used processes depending upon material, case depth, camshaft shape, size, topology and topography.
- This technology eliminates or measurably minimizes a temper back (undesirable softening) of previously hardened neighboring lobes when heat treating camshafts with closely positioned lobes. This suggests the possibility of using induction tempering in camshaft hardening. Thus, the same system could offer induction hardening and tempering of camshafts as it has been successfully done for a number of years in heat treating of crankshafts.

A testimonial of one of the users of this advanced process published in [6] could be considered an objective assessment quantifying benefits of this technology based on obtained real-life records: "The SHarP-C hardening machine helped us to reduce the camshaft's distortion down to 3–5 microns and we have been able to eliminate the entire straightening operation. So, our savings on elimination the straightening operation alone is about \$ 40,000 per year. On top of that there has been substantial improvement in the quality of the hardened camshafts, and our scrap was reduced about 1.5 %."

MAXIMIZING COST-EFFECTIVENESS OF INDUCTION SURFACE HARDENING

Technical confidence, quality, price, delivery and longevity have traditionally been the five key benchmarks in judging induction hardening equipment by commercial heat treaters [7]. Because of a number of current developments these five are joined by a six one that is equally



Fig. 9: Representatives of now-days shaft-like components that are needed to be induction hardened



important – technical flexibility. Under current conditions, heat treat contracts may move from supplier to supplier on an annual basis. Thus, suppliers trying to win these contracts may seek out and source the appropriate equipment to do the processing, purchase the equipment, start the equipment up and complete a Production Part Approval Process (PPAP) to be in production in a short period of time. In addition, the equipment must be high quality, very reliable on hand and easily accessible. Because of these market conditions modern heat treat equipment must allow easy re-tooling and re-programming to process different parts.

Even a decade ago, when discussing the subject of induction shaft hardening, it was not uncommon to assume dealing with predominately straight solid shafts with minor diameter changes. Today, the situation is quite different. The automotive industry is implementing light-weight initiatives in vehicle design to meet more stringent federal Corporate Average Fuel Economy regulations. Similar changes are occurring in off-road, aerospace, agricultural and other industries. Every metallic part in the engine, drivetrain, frame, and safety and exhaust systems is being revised to minimize weight and optimize critical engineering properties as well as residual stress distribution. In case of shaft-like parts, designers drill holes, reduce cross sections, make grooves, shoulders, and use custom shapes and alloys to accomplish these goals [7]. Fig. 9 shows some representatives of now-days shaft-like components that are needed to be induction hardened. These new challenges push heat treaters to demand innovations from induction equipment suppliers to deliver products that can perform.

Scan hardening

In scan hardening, the inductor or workpiece or both may move linearly relative to each other during the hardening cycle. Depending on the workflow of parts the system can be built as vertical, horizontal, or at an angle, though vertical scan hardening is the most popular design due to a number of reasons including a smaller footprint and specifics of quench flow.

Scan hardening systems offer noticeable process flexibility with respect to the workpiece length and, to some extent, variations in the part diameter. Scanning provides the ability to vary the speed and power during the process, which controls the amount of heat applied to different areas of the shaft.

Geometrical irregularities and discontinuities distort the magnetic field generated by an inductor, potentially causing local temperature variations altering metallurgical quality and may produce excessive distortion. For example, scan hardening shafts with diameter changes of appreciable size, variable wall thickness hollow sections and multiple holes and sharp shoulders can produce unwanted hardness pattern deviations and metallurgically undesirable structures. Additionally, it is often specified for multifunctional complex geometry components to have significantly different hardness case depths along component's length. This would naturally call for a corresponding variation of localized heat generation depth during scanning. Frequency is the most powerful parameter that directly

affects the depth of heat generation. Unfortunately, the great majority of commercially available power sources for induction heating are designed to deliver a certain frequency that cannot be instantly and deliberately changed during the scan hardening.

In many cases and depending upon component's topology and hardening requirements, the available frequency may be considerably higher or lower (in folds) than its optimal value for a particular portion of the shaft. If the available frequency is noticeably higher than desirable, it produces a smaller-than-ideal depth of the heat generation that may not be sufficient for proper austenization of the subsurface region at required hardness depth. Therefore, additional time is needed to allow the thermal conduction to provide needed heat flow from the workpiece's surface towards required depth. This is commonly accomplished by a reduction of both scan rate and power density (otherwise the surface can be overheated). Unfortunately, this adds unnecessary cycle time and can lead to undesirable metallurgical and mechanical issues related to excessive peak temperatures and unwanted distribution of residual stresses.

In contrast, if the available frequency is lower than optimal frequency, an exceedingly deep austenized layer and excessive distortion may be produced. In order to reduce the negative impact of using lower than desirable frequency, the majority of induction heat treaters are trying to suppress a thermal conduction by increasing both scan rate and power density [1].

Taking into consideration, a topology of components shown in Fig. 9, a single optimal frequency rarely exists to accommodate a wide variety of part geometries, which is why conventional scan hardening with fixed frequency must always compromise between achieving metallurgical quality, production rate and process capability. While process protocol modifications to suppress or promote thermal conduction can help reduce the negative impact of using other-than-optimal frequencies, they often cannot eliminate it and can also negatively affect the metallurgical quality, stress distribution (both: transient and residual) and distortion characteristics.

Obviously, in order to address geometrical subtleties of heat treated parts in an optimal manner, it would be advantageous to apply various combinations of frequency, power and scan rates at various stages of the scan hardening cycle. Unfortunately, the great majority of available inverters do not have such capability.

A new generation of Statipower IFP inverters developed by Inductoheat (Fig. 10) eliminates this limitation and simplifies achieving the required hardness pattern allowing independently and instantly (like a CNC machine) to control frequency and power in a pre-programmed manner during heating cycle optimizing electromagnetic, thermal and metallurgical conditions.

This technology has been on the wish list of commercial heat treaters for some time. Statitron IFP is a true digital microprocessor-based control inverter technology specifically designed for induction heating needs and allowing instant and independent adjustment of frequency (within 5–60 kHz range).



Fig. 10: A new generation of Statipower® IFP™ inverters allows independently and instantly (like a CNC machine) to control frequency and power in a pre-programmed manner during heating cycle (Courtesy of Inductoheat Inc.)

The unique ability to change the frequency instantly by more than tenfold can also be advantageous for machines that need to provide hardening and tempering operations. In this case, higher frequencies can be used for hardening and lower frequencies for induction tempering. It is reasonable to expect that most users of induction machinery will expect from induction capital-equipment manufacturers "the day after tomorrow" providing variable frequency & power sources as a standard platform maximizing flexibility and user's cost effectiveness.

Single-shot hardening

Shaft-like components (e. g. output shafts, flanged shafts, drive shafts, turbine shafts etc.) are among parts that are depending upon design specifics are induction hardened using not only scanning but also single-shot hardening. With the single-shot method, neither the shaft nor inductor move linearly relative to each other; the shaft typically rotates instead. The entire region to be hardened is austenized at the same time.

There are several ways to control heat generation at different regions of a heat treated shaft. This includes a copper profiling resulting in a variation of inductor-to-shaft coupling and/or machining different widths of the current-carrying faces of the inductor. Besides that, a magnetic flux concentrator can be attached to certain areas of the inductor to further enhance localized heat intensity. As a result, certain regions of coil copper might carry extremely high current densities. A combination of intense heat generation within the copper current-carrying face with intense heat

radiation from the workpiece's surface (particularly when relatively small coil-to-shaft air gaps are used) may lead to copper overheating. This may promote water vaporization and the formation of a steam vapor barrier in that region.

Regardless of an attempt to position water-cooling pockets as close to the current-carrying face of an inductor as possible and utilization of high-performance pumps, a coil copper might still be overheated, causing accelerated deterioration of the copper surface, which

of automotive parts achieved a twenty-fold life increase of some coils based on 2017 data collection, which is verified by the manufacturer's tool-room tag. Other benefits of novel inductor design include measurable improvement in process robustness and coil reliability [8].

Regardless of enormous advantages provided by computer modeling, an "out-of-box" thinking will still be an essential part of the technology innovations "the day after tomorrow".

NEW RESOURCE FOR INDUCTION HEATING PROFESSIONALS

Heating by means of electromagnetic induction is a topic of major significance. Recently published (September 2017) the 2nd Edition of the Handbook of Induction Heating [1] is the result of an ambitious undertaking to compile an all-new, comprehensive resource on induction heating and heat treating processes to meet the needs of the induction thermal communities (Fig. 11).

This second edition of the Handbook of Induction Heating reflects a number of substantial advances that have taken place over the last decade in the practice and science of induction heating and heat treating, computer modeling, semiconductor power supplies, quality assurance, and process technology. This edition continues to be a synthesis of information, discoveries, and technical insights that have been accumulated in industry and academia. It is expected that "the day after tomorrow" this edition will continue serving an induction community worldwide embarking on the next step in designing cost-effective and energy efficient induction heating and heat treating processes and equipment.

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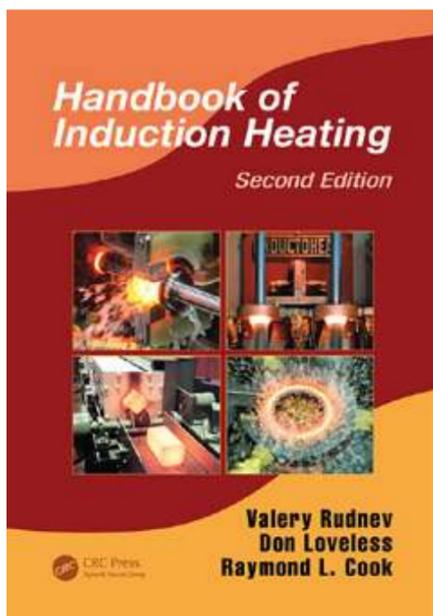


Fig. 11: The 2nd Edition of the Handbook of Induction Heating (Courtesy of CRC Press)

speeds up the onset of inductor copper cracking (due to stress corrosion cracking and stress fatigue) and eventual premature coil failure. As a result, coil life is often shortened to 22,000– 24,000 heat cycles (being industry average based on data of one of the world's largest commercial heat treat company) for certain types of shafts and shaft-like components.

Thanks to Inductoheat's inductor design (patented), one of the world's largest suppliers



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(Article Source & Courtesy: Heat Processing 4-2017 issue)

Technical Lecture Hot & Cold Oils : Apar Facts and Case Studies at Hotel Pride 20th Sept 2017

