Heat treatment in Turkey: historical development and current situation

B. Çengelli*[1] and B. Telseren[1,2]

The paper briefly describes the origins of the heat treatment sector in Turkey and its historical development. The current status, and problems and predictions for the future, are covered in some detail.

Keywords: heat treatment in Turkey, IFHTSE, MISAD, future of heat treatment, heat treaters, furnace

Introduction

Heat treatment, understood as controlled heating and cooling processes to change chemical, physical, mechanical properties of materials, has been practised in some form or other since metals were first made into implements. In Turkey, the significant events were the manufacture of Denizli Yatagan swords and Bursa knives beginning in the time of Altaylar around BC 2000, and developing particularly in the eleventh and thirteenth centuries. The foundation of MKEK (Machinery and Chemical Industries Institution) in fifteenth century (http://www.mkek.gov.tr/tr/default.aspx) represents an important step in the development of a heat treating capability. The first outsource heat treatment was established in 1951 in Karakoy Tophane as a salt bath facility by MKEK staff who had been trained abroad. These experts gradually moved to the private sector and set up new companies. The pioneers in this were Haydar Çelebioğlu and Dursun Yıldız.

There was at that time no domestic educational provision in heat treatment and the number of properly qualified people was very small. Procedures were very much trial and error based, using a master–apprentice relationship in small workshops. Hardness measurement, determination of retained austenite and decarburisation were simply assessed, material analysis was carried out by spark test, determination of low tempering temperature was based upon colour change after heating the part. Plant and equipment consisted usually of bellows, blacksmith's forge, coal, shredded animal horns and nails and water. Salt baths were used but other cooling media were unknown. There was certainly no effective preventive action relating to safety and the environment. Transport and logistics were difficult and time-consuming. There was, however, no competition so profit margins were high and growth was fairly rapid. In the absence of educational facilities, MKEK itself, with its considerable practical experience, was the 'school' and the source of new trained personnel.

A proper scientific and technological infrastructure began to be set up in the 1960s: metallurgical engineering departments were opened at Istanbul Technical University (1961, http://www.mme.itu.edu.tr) and the Middle East Technical University (1966, http://mete.metu.edu.tr/research); the TUBITAK-MAM Institute of Materials (1968)[1] and the Chamber of Metallurgical Engineers (1970)[2] were established later. Heat treatment related sectors developed: aerospace (1957), Ereğli Iron and Steel (1965), the first tool steel heat treatment company, Çelik Takım Sulama Sanayi (1966), the automotive industry (1968), and powder metallurgy companies (1969). Heat treatment conference activity began with the First Metallurgy and Materials Congress (1975),[2] the 1st National Aluminium Industry Congress (1978)[2] and the first National Casting Symposium (1981).[2]

Captive heat treatment shops were gradually established: THY (1957), Hema (1971), Taksan (1975), Seydisehir Aluminium (1975), Iskenderun Iron and Steel (1975). Turkey's first industrial heat treatment furnace manufacturer, Sistem Teknik, was founded in 1979. Between 1980 and 1990, contract heat treaters used second-hand furnaces from Europe, including vacuum furnaces. They fully appreciated the importance of understanding the diversity of cooling media and installed quality control laboratories. Captive shops using modern furnaces and qualified staff tended to be more advanced than outsourced heat treaters.

Leading people in Turkey rapidly became more widely known outside the country, for example Professor Ali Erdemir[3] has received the R & D 100 Award in tribological science four times (1991, 1998, 2003 and 2012). Prof. Cemil Hakan Gür,[4] a Fellow of IFHTSE, is appreciated globally in the field for his work in ensuring the coordination and completion of the 'Handbook of thermal process modelling of steels', the result of an extensive multinational effort. Heat treatment papers were presented in First National Industrial Furnaces (1992),[2] first National Powder Metallurgy (1996),[2] first Heat treatment (1998)[2] and first iron and steel (2001)[2] symposia.

Contract heat treaters bought new vacuum furnaces using up-to-date technology but also built fluidised bed, gas carburising and nitriding furnaces themselves in the early 2000s. The first PLC controlled heat treatment furnace resulted from an R&D project supported by TUBITAK in 2007 by Alper Isıl İşlem. Metal Heat Treatment and Manufacturers Association (MISAD, http://www.misad.org.tr/index.php/author/misad/page/3/) was founded in 2008 and is a member of IFHTSE. The first paper on occupational health and safety in the contract heat treating sector was presented by Bodycote Istaş Heat Treatment at the third heat treatment

[1]Bodycote Istaş, Istanbul, Turkey
[2]MISAD, Istanbul, Turkey

*Corresponding author, email bilgi.cengelli@bodycote.com

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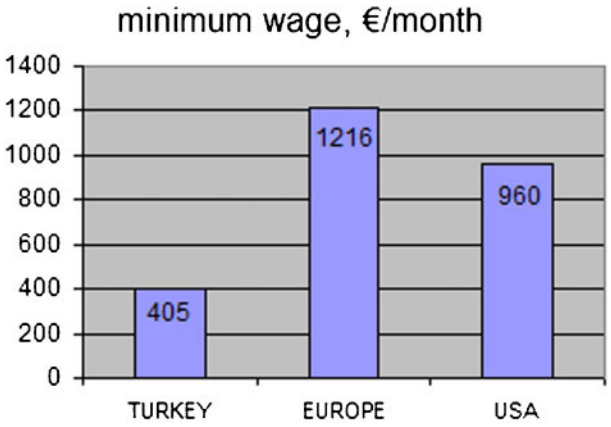
symposium (2009). The vacuum brazing process started up in 2010. The first heat treatment vocational cohort graduated in 2011, and Bodycote Istaş was the first certified contract heat treater with BS EN 9100 (AS 9100) certification. First International Surface Treatments Symposium was held and heat treatment was defined as a profession in the national occupational standard in 2011 for the first time. At present; there are forty five (45) universities having eighty five (85); programs under the name of metallurgical and materials engineering, materials science and engineering, materials engineering, materials science and nanotechnology engineering departments, offering undergraduate, graduate and doctoral educations. Twelve (12) of the forty five (45) universities and sixteen (16) of the eighty five (85) programs teach in English. Metallurgical and materials engineering (B.S.) programs of ODTÜ (2007) and İTÜ (2009) had been accredited by ABET (http://main.abet.org/aps/Accreditedprogramsearch.aspx) as being substantially equivalent. ODTÜ was eighty-fifth in World University Rankings 2014–2015 (http://www.timeshighereducation.co.uk/world-university-rankings/2014–15/world-ranking). Four year first cycle (B.S.) programs of seven of the forty five universities had been accredited by MÜDEK (http://www.mudek.org.tr) as of 01 July 2014. Research thesis executed by TUBİTAK (The Scientific and Technological Research Council of Turkey) and the universities are mainly on heat treatment of iron and non-ferrous alloys, composites, polymers, ceramics, novel alloys, bio and powder materials, welded parts, NDT methods, surface treatments, nano-technologies, tribology, failure analysis and computer aided modelling.

Current state of heat treatment in Turkey: problems and plans

Rapid growth and global financial crisis of 2008

Controlled atmosphere furnaces and vacuum technology began in Turkey in 1995. As export activity increased, the number of heat treaters increased proportionally to the rising demand for heat treatment. In response to a dramatic increase in production, heat treaters increased their capacities significantly during 2006–2008. However, when the global financial crisis struck in 2008, production fell and furnaces in outsource heat treaters were idle (http://www.moment-expo.com/isil-islem). When the signs of the impending crisis became evident in the second half of 2007, immediate measures were put in place. Employees and employers shared the burden so that emergency measures were taken largely without reducing employee numbers; for example, re-assessment of overtime, and introduction of part-time employment. Consumption priority was given only to urgent issues, rejects were minimised, great emphasis was put on customer credit control, working with unreliable customers was discontinued, costs were reduced by more efficient working practices and continuous tracking of targets. When the crisis pressure was particularly severe, reduction in personnel was achieved by keeping key qualified staff, reducing salaries, and postponing new investment. The 2008 crisis has led to new investment proposals, capacity expansion and pricing policies being more critically examined. Despite constant increases in input costs (http://www.botas.gov.tr),[5] work is currently carried out at prices equivalent to those of 2002. In this regard, heat treaters showed preference towards high value added contracts and away from investment in volume.



1 Minimum wage, 2013 (http://www.botas.gov.tr, http://www.energy.eu/, http://www.eia.gov/electricity/data.cfm#sales, http://www.dol.gov/whd/minwage/america.htm)[5–7]

Environmentally benign process

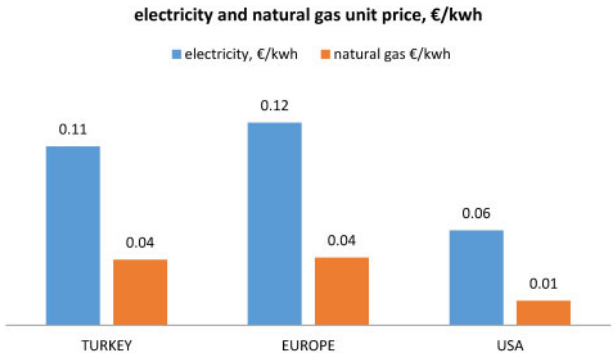
The move to environment friendly production methods in salt baths, which began in 1960 in the world in general, only began in Turkey in the early 1990s. The general trends in Europe were caught up with in the 2000s by the introduction of the latest technology currently available using vacuum. In the 1990s the industry only operated second hand furnaces.

Qualitative improvements

High quality production was ensured by using importing furnaces operating on the latest technology and software, as well as by using high quality domestic manufacture from the early 2000s. The result is that Turkish practice is on a level with that generally expected in Europe; there is no difference in terms of machinery, know-how, software, international quality certification, quality control systems and equipment, environment and safety, and fully qualified personnel. Thus it has been relatively easy to supply export-oriented sectors, demanding high speed and quality standards, such as automotive, general machinery, and aerospace industries. The heat treatment market will be enlivened by increased shift in European production in to Turkey. Companies in Europe have, in general, solved environment, energy and safety problems, but Turkey still has some way to go in this direction.

Heat treatment export is very much indirect since almost 50% of heat treated products are exported. Although there is a negligible amount of heat treated products directly exported, there are more than 60% exporting of heat treatment furnaces manufactured in Turkey. Heat treatment service is done very locally and heat treaters are generally located nearby their customers for fast delivery, low transportation cost and eliminating transportation problems (http://www.moment-expo.com/isil-islem). Investment in modern technology is supported by professional management software, simultaneous control, the highest level of traceability, barcode applications, and automation.

Heat treatment is energy and labour intensive sector so energy and labour costs are main components of cost analysis. Therefore, minimum wage, electricity and natural gas prices had been given in the Figs. 1 and 2 to compare with Europe and USA. Labor cost in Turkey is about three and 2.4 times less than Europe and USA respectively. On the other hand electricity and natural gas price of Turkey are equal to Europe's but electricity is 2 times higher, natural gas prices is 4 times higher than USA.



2 Electricity and natural gas prices, 2014

The main technologies and their distribution in Turkey is given in the following Fig. 3. Induction machines, salt baths and sealed quenched furnaces form the main group and nitriding and vacuum furnaces following them. New equipment investments are continuing.

Powerful trade association

MISAD was founded in 2008, with a view to finding solutions to common problems in the heat treatment industry, and to provide (http://www.misad.org.tr/index.php/author/misad/page/3/, http://www.moment-expo.com/isil-islem):

(i) a fair, competitive environment
(ii) human resources development and management quality
(iii) cooperation with similar organisations in the sector internationally
(iv) organisation of effective activities
(v) strengthening R&D through industry university relationships.

The heat treatment sector in Turkey includes many SMEs – everyone knows everyone else! There are about 200 heat treaters in with a total annual capacity of about 200 000 tons. MISAD has 31 members representing 70% of the total capacity. MISAD itself is a member of IFHTSE. Among its activities have been:

(i) an exchange with German heat treaters
(ii) creation of the first heat treatment vocational school
(iii) setting of heat treatment professional standards
(iv) training for workers who are not graduates of a vocational high school
(v) certification of heavy and dangerous work as a legal obligation.

MISAD's plans include courses for members on:

(i) Turkish commercial legislation
(ii) ENVER (energy efficiency act legislation)
(iii) cost accounting in heat treatment
(iv) heat treatment standardisation
(v) heat treatment failure analysis through collaboration with faculty members of universities for engineers
(vi) heat treatment specifications for customers
(vii) environmental legislation
(viii) information.

MISAD aims, for the future, to:

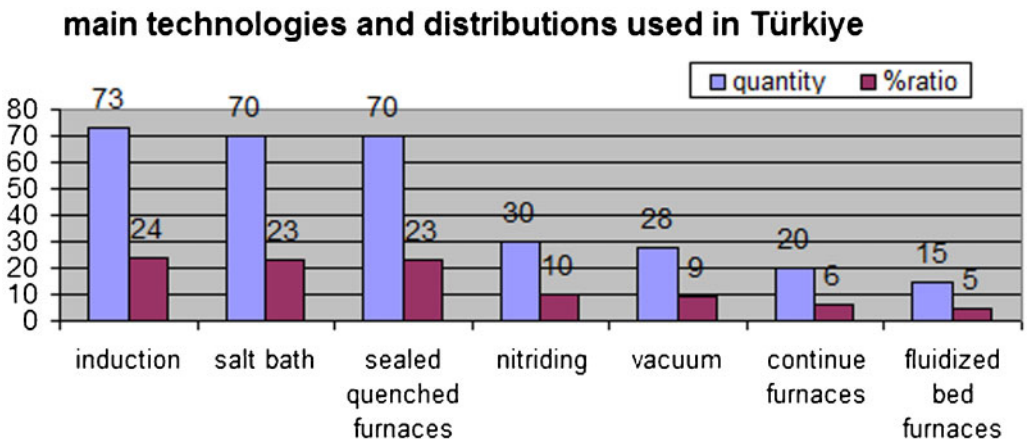
(i) educate qualified staff at high school and undergraduate level, to promote education in the workplace, to ensure materials, manufacturing, equipment, quality, standards, maintenance, environmental legislation, occupational health and safety training for all employees. Inviting the heat treatment industry related companies across the country to MISAD
(ii) reduction of the sector's large inventory
(iii) organise training on heat treatment, quality, production, management and materials
(iv) assist members in the European Union harmonisation legislation
(v) encourage collaboration with similar domestic and international organisations
(vi) find solutions to rising energy costs
(vii) establish a laboratory with a very strong infrastructure.

Recognition of heat treatment as professional activity

Since heat treatment was defined as a profession for the first time in 2011, education, infrastructure, organisation, energy, safety, the environment, unfair competition, etc., could only be effectively addressed since that time. As yet there is no heat treatment commission in The State Planning Organization. Universities, the State Planning Organization, industry, energy, environmental, labour and social safety, education ministries, chambers of commerce must come together to plan the future of the sector.

Energy problem

The continuing need to import energy creates problems from both strategic and economic viewpoints. Solar, wind, renewable and environmentally friendly energy sources have not been used yet in heat treatment. There is no effective process heat recovery practice. Energy management in



3 Heat treatment technologies used in Turkey, 2013

furnace plant and equipment, and the use of insulation materials are important factors in reducing energy costs, but apart from the most recent investment, much of the plant and equipment at present in use is old, therefore energy and maintenance costs are excessive. There are energy subsidies from the State, but such aid is not yet widespread among heat treaters. The Energy Ministry's 2023 targets include zero dependency on imported electricity and natural gas. If this can be achieved, it will obviously have significant advantages for heat treatment.

Environment

Waste management, disposal and recycling during heat treatment are common practice. The target is to move towards environmentally benign heat treatment plant. Energy recovery is a very important part of this and there are some State-supported projects. Management of noise, heat, fume, cooling media, chemicals, contaminated waste, etc. occurring in heat treatment processes must accord with all legal requirements; inspections and awareness training are carried under significant Government pressure. Collaboration with licensed environmental engineers or licensed environmental consulting companies is mandatory. Heat treaters began to turn to eco-friendly, disciplined, planned, efficient companies by collaborating with the organised industrial zones established from 1962.

Occupational health and safety

Safety and occupational health studies complying with legislation in heat treatment are progressing very quickly and most heat treaters are already at a level equivalent with Europe. Audits with significant Government backing are carried out within the framework of the EU harmonisation process. These are obliged to involve a licensed occupational safety specialist. Training in risk analysis, in accordance with the standards and regulations, is available to create awareness among employees; there is increased understanding that work and environmental accidents are minimised by working within the law. Work and environmental accidents are reported periodically and follow-up action is taken.

Competitive context

The future in terms of pricing and competition, however, is seen to be much more difficult. Reducing prices is easy, but it is very difficult to maintain low prices and significant fluctuations are inevitable. Many companies can handle costing very well, but some cannot. Therefore, MISAD planned and carried out training in cost accounting. One problem is the tracking of the sector demand, which makes investment decisions difficult. Excess capacity and unfair competition are problems due to lack of general understanding of the total economy. Overcapacity in some areas has led to idle vacuum furnaces, depressed prices, and excess profits. Heat treatment is labour intensive and artificially reduced pay rates lead to unfair competition. Investment costs are high due to high interest rates. Not only is new furnace plant and equipment using imported advanced technology expensive, but their maintenance is also import based and expensive. Second hand furnaces need much more maintenance, they are not energy efficient and their life is shorter. Plant and equipment can be built in Turkey but the necessary capacity is in need of development. This sector is intimately related to the industries it serves and to the national energy situation and to the general economic difficulties. The solutions will lie in the direction of economic stability and greater diversification into higher value products.

Customer and contract problems

Import oriented energy dependency, expensive, constantly increased and prepaid input prices are significant problems for heat treatment, since the processes are capital, energy and labour intensive. Energy costs of 15–30% and labour at 30–40% means a low profit margin in heat treatment. Invoice settlement averaging over 90 days means a 3% financial loss. Input price increases cannot be passed on to the customer immediately. Customers ordering large volumes demand price reductions and long settlement periods. There is very great customer reluctance to sign contracts, so that resources are expended on unconfirmed orders, partial payments and absorption of rejects. Heat treatment usually takes place in the final stage of the production of an engineering component so that the difficulties arise late in the cycle, and insurance against payment failure is not common practice.

There is very limited understanding on the part of the client of the materials selection, design and process sequence required for successful manufacture. The main industries carry out materials-based R&D with overseas OEMs and heat treaters are not properly considered in product development stage. This results in delivery delays and faulty heat treatment. These problems can be eliminated by using metallurgical-material science engineers in OEM and sub-tier suppliers as well as heat treaters, arranging heat treatment trainings for customers and integrating heat treaters to FMEA studies executed by OEM and sub-tiers.

Inadequate contract review stage in new product start-up process

Most of the quality problems arise when risk evaluation and contract review are not properly carried out at new product start-up. Fully understanding customer requirements before accepting the job, assessing all risks related to feasibility, investigating the operating conditions and application type of the components concerned, before and after heat treatment operations – plus full discussion with the client, are aspects that need considerable improvement. Effective training, best-practices, audits, etc. will help to solve these issues.

Predominance of captive heat treatment shops

Heat treatment in Turkey these days is 80% in-house and 20% outsourced. There is a common assumption that heat treatment costs can be reduced simply as a function of a captive process. In-house heat treaters tend to believe that prices are lower as a function of predictable furnace loading, but much of the cost analysis is wrong. The contract heat treatment sector should be encouraged since they can be essential strategic partners using new equipment and experienced and skilled manpower.

Lack of fully accredited, responsive and affordable failure analysis resources

The number of responsive, good value, accredited, properly equipped and experienced research institutions capable of failure analysis is in urgent need of increase. Tests and reports are time consuming and very expensive at the existing facilities in universities, TUBİTAK, KOSGEB, etc.

Human resource problems

The number of qualified technicians and heat treatment engineers is too small. Vocational heat treatment course availability must be increased. Heat treatment is actually mandatory in some universities, in others it is optional, and in some it does not exist at all; it would be beneficial to make it a compulsory course and increase the number of heat treatment 'clubs' in the universities.

Measurement, control, software

There is high quality production fulfilling CQI-9, NADCAP, pyrometry, AS9100, TS 16949 and other quality management systems requirements. This is performed mainly by continuous monitoring, recording and verifying all process parameters in heating and quenching systems equipped with alarms, good qualified employee, metallography and mechanical test laboratories. Additionally, high level IT systems, barcode applications and automation systems enable fast and safe traceability and accessibility to data from anywhere. Also, non-destructive testing (NDT) and simulation studies on heat treatment have been conducted by the universities.

Future of heat treatment sector

It must be compatible with Turkey's 2023 and world heat treatment vision. Therefore, it was aimed to meet the heat treatment needs of the following relating sectors in the best way:

(i) innovations in heat treatment processes and applying high tech heat treatment technologies for best optimisation of time, energy, man-power, quality, cost, material, environment, testing, monitoring
(ii) increasing in exporting of high tech furnace and equipment
(iii) elimination of quality, deformation, crack problems
(iv) convert all heat treatment plants to sustainable environmentally friendly facilities
(v) providing best heat treatment servicing together with high tech equipment, qualified employee, infrastructure to realise 2023 targets given as below:
- to increase number of vehicle production from 1 million/year to 4 million/year[8]
- to increase automotive export from 19·5 billion dollar to 75 billion dollar. Turkey has become the largest commercial vehicle producer in Europe and in 2010 ranked sixteenth of all automotive manufacturing countries, producing more than 1 million vehicles and exporting around 70% of domestic production[9]
- to increase Research & Development expenses to internal revenue ratio from 0·9 to 3% (Ref. 1)
- to realise domestic aircraft and satellite production
- increasing domestic production in defence and aerospace industry
- increasing domestic production in energy sector
- increased production rate in all other sectors machinery, medical, chemistry, steel industry, etc.
- production of lightweight and environmentally friendly products with outstanding properties
- production of high value added products rather than traditional ones, i.e. produced by brazing, HIP, thermal spray or combination of them, etc.
- improving in economical growth. Annual growth was realised as 5·2% between 2002 and 2012, 2·2% in 2012 and 4% in 2013. Turkey can take place among first ten countries having largest economy in 2030.[10,11]

The heat treatment and surface engineering sectors in Turkey have a good future because of a stable political and economic structure, and experience in handling crises. The strong, dynamic market, the scientific, dynamic and highly qualified human resources can all be very attractive to European company investment. In cast steel product heat treatment, the Turkish position is better than that in Europe. Even given the shortcomings described above, the current production figures for surface treatment was seen to be good in the international symposium on surface processes held in 2011.[2] Deveopments in the field of nano-materials in Turkey is now an indispensable part of the production picture, and there are companies participating in projects under the EUREKA E!-SURF umbrella and R&D joint projects are being developed with EU countries. Foreign and domestic research and development projects are carried out using the METU and other university heat treatment, surface treatment, nano-technology, energy, materials, welding, NDT, computer simulation facilities. Universities and research institutions, developing plasma spray coatings and new generation of biocompatible medical coating materials, are reducing the foreign dependency to USD 3·12 billion in 2015; market power is expected in the high-tech medical market (85% export) along with high-tech employment opportunities. Sakarya University Thermal Spray Coatings R&D Centre has been established to handle both domestic and overseas projects. The share of R&D from gross national product growth in Turkey has increased from 0·2% to the current 1% and the target is to reach 3%. High project costs, inadequate budgets, and unsatisfactory university-industry relations are seen to be inhibiting factors in innovative studies. Main needs are: awareness of what innovation means, sound knowledge of the basic techniques of creative thinking, and understanding of the obstacles to the transformation of ideas into innovative practice, a well functioning suggestion system, encouragement for every employee to put forward innovative ideas, and management prioritisation of innovation.

R&D subsidies, the EU Framework Programmes starting in 1984, TUBITAK in 1995, KOSGEB in 2004 and SAN-TEZ in 2007, have all been launched, but the sector did not exploit the opportunities properly or sufficiently. There are knowledge gaps in Turkey relating to HIP, vacuum brazing, ion implantation, thermal spray, intensive quenching and effort is being put into these issues.

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