Resource savings and energy efficiency in heat treatment shops

by **Olaf Irretier**

During the last years the topic of energy efficiency has taken place in nearly all areas of industrial production. The general resource and environment protection, the rising energy prices and the aim of process cost reduction release currently a row of discussions and measures. In the future also the legal national and international regulations have to be taken into account and lead into further increasing activities concerning energy-efficient arrangements and procedures. The present contribution treats the different arguments and possibilities of the energy efficiency in heat treatment and industrial furnace technology and shows practical aspects and measures to its increase.

Energy efficiency improvement, reduction of energy costs and gas emissions and thereby relieving the environment: These are the aims of the first European norm introduced in August, 2009 EN 16001 as well as the worldwide valid norm ISO 50001 for operational energy management. Both intend the introduction of an operational energy management system and define in addition obliging criteria for producing enterprises.

Thus the worldwide consumption of raw materials has increased during the last 30 years to the primary power production about 70 %. Up to 2030 an increase of the worldwide primary energy consumption compared to 2006 of about over 45 % is expected (World Energy Outlook in 2008). On the other hand Germany aims at the decline of the greenhouse gases for 2012 of about 21 % compared to 1990. Till 2020 even a reduction of about 40 % of the greenhouse gases should be achieved. The other long term aims were fixed in 2008 at the G8 summit in Japan with halving the emissions till 2050 which requires an increase of the energy efficiency of about 3 % yearly – currently the annual increase of the energy efficiency is less than 2 %!

It is obvious that the European Union acts and will further act to increase the efficiency of the energy-intensive processes in particular. Other demands for the environmentally compatible design of energy-pursued products (ecological design directive) were fixed by the directive in 2006 / 23 / of the EU. For the future the EU has fixed other aims, among other things the increase of the energy efficiency of about 20 %, the reduction of greenhouse gas emissions of about 20 % and the general support of renewable energy. With the "New Approach beginning" of the EU (the EU harmonisation, CE marking, conformance assessment, etc.) only the products may be brought in trade which correspond to this directive.

Topically the EU commission has provided a suitable study of the industrial furnaces which contains among other things also the definition of energy efficiency.

ENERGY BALANCE IN INDUSTRIAL FURNACE TECHNOLOGY

During every kind of combustion process, a large amount of CO_2 is produced. 40 % of the industrially used energy is used for industrial furnaces, corresponding to a cost volume of about € 30 billion. In spite of energy saving in the last decades the consumption amounted in 2005 in thermo process technology of about 270 TWh – an energy potential to supply Bavaria with energy for one year. Modern industrial furnaces compared with older ones save about 20 % in the wall insulation, 75 % in exhaust gases and about 60 % in protective gases. The use of other future potentials allows energy savings of about 10 %.

MEASURES TO INCREASE THE ENERGY EFFICIENCY IN INDUSTRIAL FURNACES

Concerning the measures to increase energy efficiency there are many different possibilities which are shown in **Fig. 1** in an overview diagram and in **Table 1** in detail.

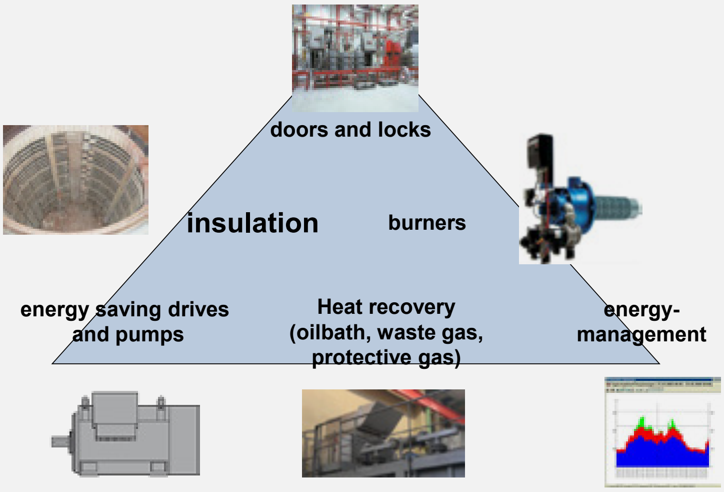


Fig. 1: Measures to increase the energy efficiency

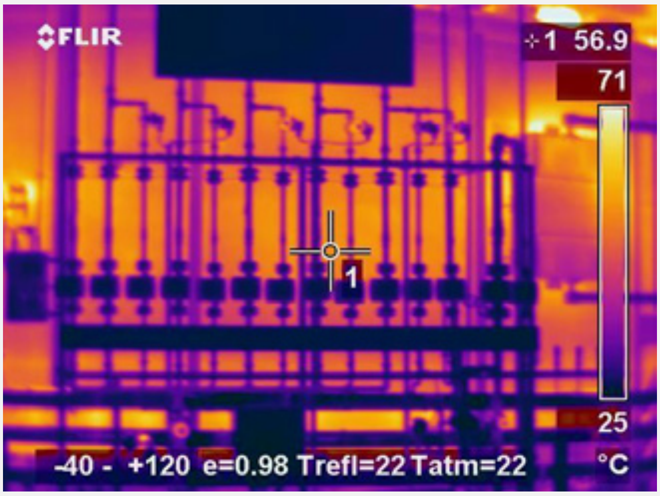


Fig. 2: Picture made with a thermographic camera

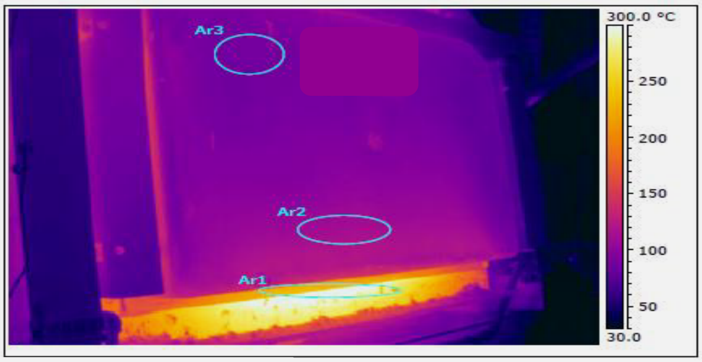
The assessment of a more efficient energy use in heat treatment shops is connected in general also to the question, how the available warmth, i.e. the energy content of a component, of an atmosphere or a material can be transferred by a temperature gradient to another medium or the surrounding. The problem which is to be solved is that the available warmth or heat amount arises discontinuously and is dependent on the time of day or the season. That's why a suitable energy management system helps basically.

Insulation – Thickness and material

High temperature processes have very special requirements to furnace insulation which have been complied by optimised application of insulating materials (fibre, wool, refractories and stones). In the last decades the reduction of energy consumptions in high temperature processes was up to 30 %. The quality of the industrial furnace is substantially influenced by the choice or combination of the insulants concerning energy consumption, heating and cooling speed, energy losses,

Table 1: Measures to increase energy efficiency

Primary measures		
saving of		
gas	use of burner waste gases	preheating of parts
		heating of washing mashines
	use of reactive process gases	heating
	recuperative heating of burner air	increase of efficiency
current	effectiveness of fans	increase of efficiency
	effectiveness of pumps	increase of efficiency
	effectiveness of electric heating	substitution
	effectiveness of drives	increase of efficiency
current or/and gas	use of energy/heat of quenching bathes	heating washing and drying devices
	weekend operation	minimizing energy consumption
	process optimization	minimizing energy consumption
Secondary measures		
	external energy use of quenching bathes	heating of rooms and water
	use of burner gases	heating of rooms and water



Ar1 max. temperature	320 °C
Ar2 max. temperature	220 °C
Ar3 max. temperature	110 °C

Ar1 max. temperature	250 °C
Ar2 max. temperature	260 °C
Ar3 max. temperature	110 °C

Fig. 3: Picture made with a thermographic camera in a chamber furnace door

Fig. 4: Picture made with a thermographic camera at the internal door of a chamber furnace

memory warmth and therefore energy efficiency. It is worth noting that light insulants show a low mechanical firmness, however, a high insulating property and a low heat accumulator capacity. The maximum operating temperatures are relatively low (except in the case of the ceramic fibre). Heavy insulants are mechanically highly loadable and have a big heat accumulator capacity and a lower insulating effect. Pure fibre-insulated furnaces have, with the same insulating strength, a lower memory warmth, but a higher radiation loss. Therefore, it depends on the operating method whether a fibre insulation is economic or not.

A statement due to insulating design and density of refractory arrangements can be reached with the help of pictures of a thermographic camera (**Fig. 2 and 3**).

The sealing of furnace doors with suitable fibre tape or regrinding of the furnace door stones is especially important for a reduction of heat losses. A thermally critical place are basically the burner flanges. In this area temperatures from 100 to 200 °C are measured generally. Also near the insulation of the internal door of chamber furnaces suitable temperature measurements should be carried out (**Fig. 4**).

At high temperature processes the furnace insulation plays an important role which has been fulfilled during the last years by the optimised application of insulating materials (fibre, wool, stones). Thus can be reduced, for example, by application of microporous insulating boards (0,025 W/mK) as rare side insulation, the furnace wall losses about 20 % which corresponds to a decrease of external furnace wall temperature of about 10 °C. The pay back times are appr. 3-5 years.

Burner Technology

The cost effectiveness and efficiency of a heat treatment process depends in particular on the energy consumption per components or weight of the components. Modern industrial furnaces are equipped with recuperative or regenerative gas burners. Currently used gas burners have integrated recuperators which reach efficiencies from about 70 % under optimum circumstances. Regenerative burners achieve theoretically 85 % efficiency and more (**Fig. 5**). More aspects of burner technology in energy saving concepts are explained in several other reports.

Fig. 5: Recuperative gas burner (source: Noxmat)

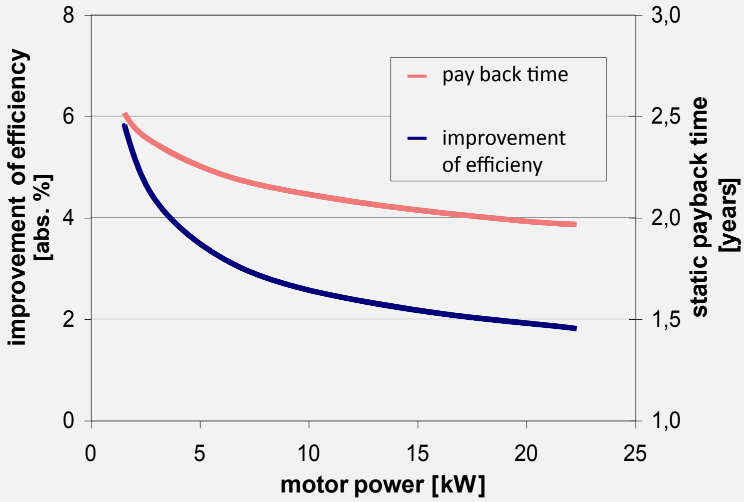


Fig. 6: Efficiency improvement EFF of electric drives (source: Aichelin)

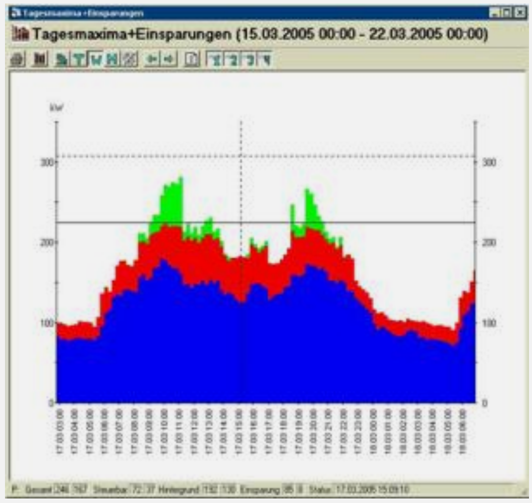


Fig. 7: Top current management

Drives and Power Management

In addition the use of drives and engines of higher energy efficiency class which are moved in connection with future maintenance and servicing makes sense. The pay back times for this parts are at appr. 1-3 years (**Fig. 6**).

For many years the energy-saving by using energy management systems is discussed very intensively. For short time running thermal processes of a quantity production a suitable load or top current management (**Fig. 7**) energetically may be absolutely sensible and be connected with a high cost effect. Long term carburizing processes e.g. in heat treatment shops gives only low possibility of the chronologically adaptable creation.

In addition the weekend circuit (with loads in the furnace), i.e. a reduction of the furnace temperature, for example, 500 °C instead of temperatures above 900 °C lead to a reduction of wall losses of about 20 % (protective gased furnace) or 50 % (non-protective gased furnace). To carry out an evaluation, a suitable capture of the energy consumption is necessary which is to be compared to increased servicing and wear costs.

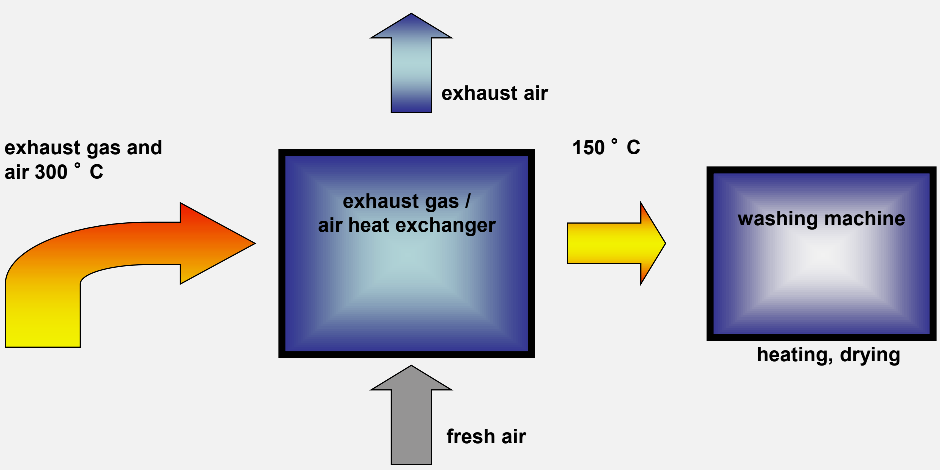


Fig. 8: Waste heat recovery (example: furnace exhaust gases) for heating and drying of a washing arrangement

Heat Recovery

Heating of Washing Machines

For heating of washing machines basically burner exhaust gases as well as the use of the heat potential of quenching baths can be used. The energetic use of burner exhaust gases (exhaust gas temperature before heat exchanger higher than 300 °C / after heat exchanger lower than 150 °C) which can be used about bypass and water heat exchanger for the heating of cleaning facilities usually amortise after 4-6 years. For heating of washing water in washing machines a temperature difference is required by at least 15 K. e.g., oil bath temperature 80 °C, i.e. heat of the water on max. 65 °C is possible.

The heating of a washing machine (60-80 °C) or of a complementary component drying after the cleaning process can occur, e.g., through waste heat utilisation from quenching baths, the rejected heat processes or the burner exhaust gases over heat exchanger (**Fig. 8**). With waste heat utilisation from the quenching bath temperature differences should be given between oil bath and cleaning bath from higher than 20 °C. The measure entails respected pay back times of 3-5 years. When using waste of oil baths for the drying (with or without vapour condenser) in cleaning arrangements, pay back times of also 3-5 years are to be expected for these measures (**Fig. 9**).

The following example shows that the economic efficiency of these measures can be at about 3-5 years: Burner exhaust gas with temperatures from up to 450 °C are supplied about exhaust gas-collective channel of the high temperature furnace over heat exchanger of the washing machine (**Fig. 10**). The saving of the burner gas can be in such a case at about € 5,000 per year.

Drying

In case of using waste heat of oil baths for the drying (with or without swath condenser, see **Fig. 11**) in pusher type furnaces which have an annual coolant need of about 10,000 to 20,000 m^3 an energy conservation of about 10-20 kW is possible. This corresponds to a pay back period of 3 years.

Due to an example of a screw factory is the usage of distiller's exhaust gases and waste gases for drying in the washing machine an economically efficient measure: The energy conservation is up to 50 kW, which corresponds to a cost saving of about € 20,000 (pay back of approx. 2-3 years).

Building Tempering

To heat a building a lot of possible heat energy suppliers described in this article can be used. It has to be noted that in special periods the warm potential cannot be used (summer). Moreover, a cooperation with the TGA is necessary.

GUIDELINE ENERGY EFFICIENCY

To be able to value the situation concerning energy efficiency in the production process, all available operational energy data should be determined first. The determination should be composed of the present consumption data of all furnace arrangements as well as of the data to peripheral arrangements in the heat treatment shop (gas, power and water consumption).

In addition the responsible staff are included at the beginning of the project, they are familiarized with figures and values and informed about the intention of an energetic optimisation.

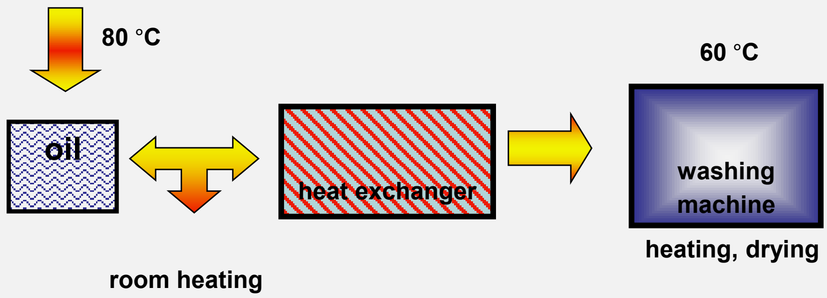


Fig. 9: Waste heat recovery (example: oil bath cooling) for heating of rooms or washing machines

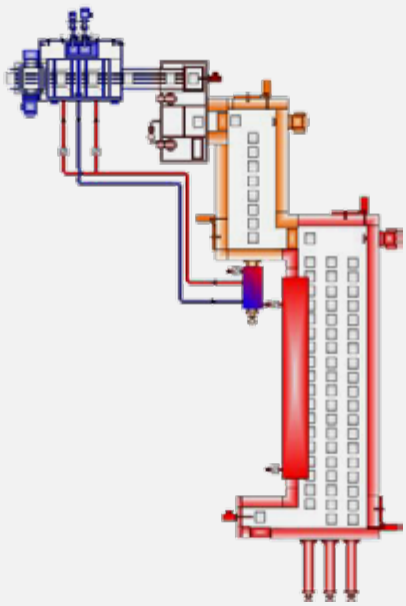


Fig.10: Waste heat recovery of burner gas for heating of the washing machine (source: Aichelin)

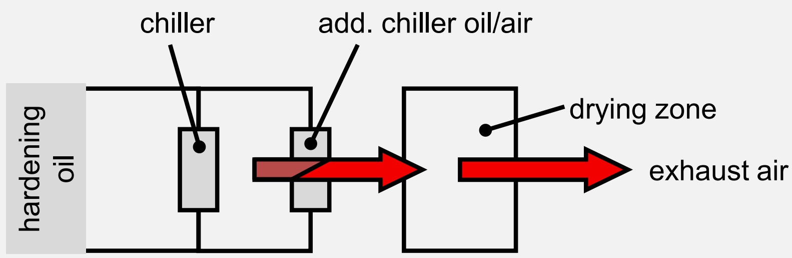


Fig. 11: Waste heat recovery of oil bath for drying

After collecting the different energy data the possible weak points of the process are examined. These are depending on the kind of the location and on the available furnace arrangements. Weak points can appear where energy is used or can escape uncontrollably, e.g. in „heat bridges" of the furnaces like doors and lids, flanges, corners and connecting parts. On the basis of the numerical values which are determined in the analysis realizable measures are suggested to increase the energy efficiency.

The expiry of the energy efficiency analysis:

1. Problem description, objective, demarcation,
2. Overview with information of the furnace programme and heat treatment processes,
3. Collecting of ground plans of the company,
4. Listing of the heat-treated amounts and loads, estimated due to days, weeks and months,
5. Arrangement of technical data of the furnaces,
6. Sighting of maintenance and installation plans for electricity, gas, cooling, water,
7. Listing of the relevant consumers in energy type or energy source (for example electricity and water),
8. Arrangement of available data of single consumption and performance measurements,
9. Listing of received energy sources with calculations and amounts of the last years,
10. Sighting of the technical documents about waste disposal plants (waste water, exhaust air, rubbish).

Afterwards a possible measure plan is suggested and conclusions for the improvement of the operational energy situation can be drawn. Basically there should be made a distinction between the structural, organizational and technical measures. Initial rough cost overviews for the suggested optimisation should be compiled and be discussed.

CONCLUSION

The importance of energy efficiency has won increasingly in industrial processes in the past. The possibilities of the efficiency increases arise on one hand from the optimisation of single processes, on the other hand from the comprehensive consideration and improvement of chained process and manufacturing procedures.

Hence, the target consists in grasping cross-process material and energy flows, in balancing and in using the technical and economic possibilities of the energy conservation by e.g. shortening of process times, energy storage, waste heat utilisation or energy recovery. Besides, it is worth not only to understand the heat treatment processes but also the cooling processes and to realize suitable strategies taking into account the technical feasibility and the observance of the sets of rules and demands relevant for the environment. Comprehensive approaches of the thermal processes taking into account all dimensions of influence are essential and allow finally technically feasible and commercially interesting solutions on the subject "energy efficiency". Here it is a matter to recognise the potentials from heat treatment, furnace construction, heating technology and cooling technology across the systems. There are possibilities enough!

The examination and realization of energy-efficient measures in hardening shops compellingly requires a cooperation of the departments of machine and investment technology and the hardening shop itself. The essential steps of a suitable analysis to the energy efficiency are:

- Stock-taking,
- Weak point analysis,
- Technical assessment,
- Plan of measures and economic efficiency.

Due to the analysis some measures are recommended which should be realized subsequently:

- Elimination of the weak points and energy losses,
- Implementing of an energy efficiency concept and an enterprise-internal energy policy.

With the implementation of future measures it is important to consider qualitative and organizational aspects, i.e. the workflow in the company must be performed reliably and undisturbed.

In cooperation with measures relevant for environment and for energy also the positive effects on employees due to security, health and comfort have to be considered which increase the motivation of the employees to energy-conscious thinking and acting and which support the conveyance of the energy-consciousness to suppliers and customers.

LITERATURE

[1] Beneke et al.: VDMA/TPT: Seminar Energieeffizienz für Thermprozessanlagen, 2009

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