The CAB profiling system as a quality control tool

Profiling systems (temperature data logging systems that travel through the furnace with the product) have been an integral part of the CAB brazing process for over ten years. Their use has mainly been restricted to use as an analysis tool when production problems occur, or as a tool for establishing braze profiles for new product development. In this editorial we look at a new development which uses the profiling system as a tool that can be used regularly to monitor furnace conditions as opposed to product temperature, the rationale being that if furnace conditions change it will affect product quality. We look at how this concept was developed from quality systems already operating in the electronics industry, and how the hardware and software needed to be engineered to cope with the harsh conditions in the aluminium brazing industry. The potential advantages of a CAB system which surveys the furnace are examined and examples are given not only of how quality can be checked on a daily basis, but also how file archiving can help with quality audits. The use of SPC and trend analysis in predicting out of tolerance conditions is also considered. Finally the report show the results of trials carried out at customer plants and evaluate how every day furnace conditions such as loading can be compensated for.

Dave Plester
Datapaq Ltd., Cambridge, Great Britain

Tel. +44 / 1223 423141
Email: dave.plester@datapaq.co.uk

Introduction

The temperature profiling system, which monitors product temperature as it travels through the CAB furnace, has long been a part of the brazing process (**Fig. 1**). Introduced 15 years ago the profiling system has been a vital tool in helping manufacturers to develop brazing profiles for new products and to analyse production problems that occur from time to time.

The use of a profiling system on a daily basis for ensuring the brazing profile is within specification, i.e. as a quality tool, has been limited due to several reasons; firstly the profiling system when combined with a test product and thermocouples is awkward for one person to load onto the furnace. Secondly to obtain useful data for QC analysis, the conditions for the profiling operation must be repeatable. This means that small details such as the thermocouples being in exactly the same position in the product for every trial need to be considered, and as most people who have carried out profiling runs will testify to, it is difficult to position a thermocouple in exactly the same position in the fins of a radiator from one run to the next (**Fig. 2**).

Finally the profiling operation and analysis of the results has been, and remains an operation that requires a degree of technical skill, which means that QC personnel need to be involved in carrying out the trials on a daily basis to build up meaningful data for quality programme. Today however QC personnel are in short supply given the constant loss of manpower within the industry, and their time normally does not stretch to profiling the CAB furnaces on a daily basis, as desirable as this may be.

Fig. 2: Positioning a thermocouple in the fins of a radiator

Fig. 1: Profiling in a CAB furnace

Experience of other industries

Why the need though for profiling to be used as part of a QC programme? In other related industries, where continuous thermal processing takes place, it is becoming more desirable (in some cases necessary) to monitor the temperature profile of the oven / furnace as a method of verifying that at regular inter-

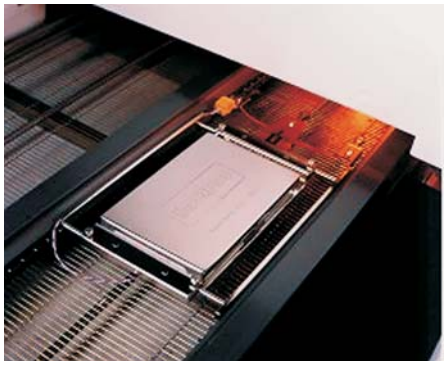

Fig. 3: Process profiling in the electronics industry

vals process conditions have been checked and are within tolerance. Further, that an electronic record (and even hard copy) of the thermal profile be kept for future reference if required.

Such industries include:

- Electronics, where printed circuit board manufacture involves passing the product through a reflow solder oven. In this industry a 'Survey' system (**Fig. 3**) has been developed to travel through the oven monitoring the temperature profile from fixed sensors. This is used in conjunction with profiling systems that travel through the oven to monitor the product (PCB) temperature.
- Aerospace, where regular 'surveys' (furnace measurement) of either batch or continuous furnaces are carried out. In these surveys the actual temperature of the furnace at specific points is compared to the set temperature, and must be within set limits to comply with the relevant specifications.
- Automobile and commercial vehicle manufacture, where even non safety critical processes such as paint curing are regularly monitored to comply with customer requirements.

Development of a new concept

Having discussed the limitations of a regular profiling system as a quality tool it still remains a goal for many organisations. Some manufacturers have even constructed their own 'one-piece' QC profiling tool (generally built around a commercial profiling system) to overcome the problems of handling and consistency of measurement. So given the desire for a QC profiling tool that can be used on a regular basis it was decided to take a fresh look at the problem. The design criterion was:

- A profiling system that would be light and easy for one person to position on the furnace belt,
- Ability to get an accurate, consistent and repeatable measurement,
- De-skill the use of the system,
- Increase the software capabilities to give full SPC and trend analysis, while simplifying the day to day tasks such as programming the data logger and storing the data from the runs.

After examining the way other industries tackle these problems it was decided to adopt the concept of process monitoring, which works on the principle that any variation in furnace temperature seen from run to run indicates that there may also be a variation in product temperature, which could in turn lead to product quality being affected.

The QC tool used to best effect in the electronics industry to monitor the furnace profile on a regular basis was the 'Reflow Survey' system, and given the similarity in processes (continuous heating process in order to achieve a permanent joint), the design of the new CAB Surveying system was based on this design.

Advantages / disadvantages of surveying the process

The potential advantages of surveying a CAB furnace on a regular basis, when looked at from a QC point of view can be summed up as follows:

- Regular (shift / daily / weekly) indication of process being within specified tolerances
- SPC analysis of individual lines (furnaces) possible allowing easy comparison of capability
- Early warning of process drift before product quality affected
- Easier handling as the system is all-in-one rather than a product attached to the profiling system
- Consistent and repeatable data as thermocouples are held rigidly in position, so eliminating the variability of thermocouple placement in the product
- Regular monitoring becomes routine operation as this can become a line operator function if necessary

The perceived disadvantage to process monitoring, is changing the mindset of the user. The industry has for the past 15 years grown used to monitoring the product temperature, so is it possible to introduce the concept of furnace temperature monitoring instead? In fact this is not such a difficult question as there is still the need to carry out product monitoring for development and fault-finding operations. Process monitoring does not replace the normal profiling that manufacturers are used to; it is a completely new solution to a new challenge – which is regular profiling for QC purposes.

Meeting the design challenges

Mechanical design

Thermocouples

These are a consumable and generally not a lot of care is given to the selection and placing, but this can have a great effect on the quality of the collected data.

Thermocouple positioning

Fig. 4 illustrates that thermocouples are an integral part of the CAB Survey system. They are held in a fixed position to ensure repeatability of measurement from run to run.

Measurement consistency

A thermal 'damper' is fitted to the hot junction of the thermocouples (Fig. 4) to ensure consistency of measurement by protecting the hot junction against transient heat spikes as it travels through the furnace. The thermal dampers also simulate product temperature to allow a realistic profile to be observed.

Heat transfer

The arms holding the thermocouples are designed to be suspended just above the furnace mesh belt to prevent heat transfer from the belt to the thermocouple, which may affect the measurement.

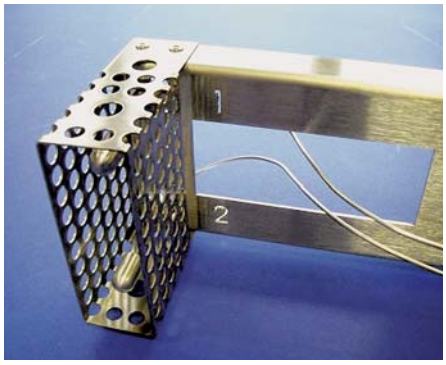

Fig. 4: Thermocouples rigidly fixed in the arms of the Surveyor system

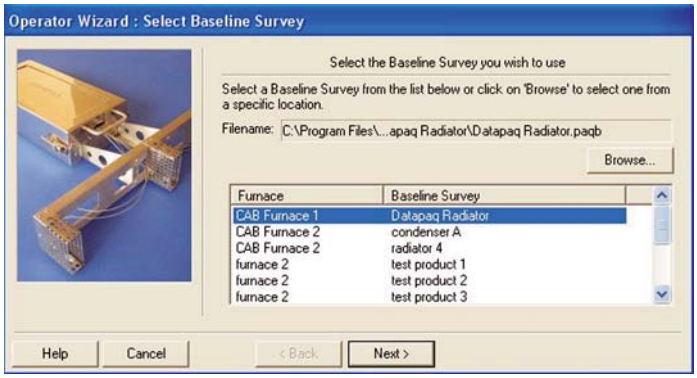

Fig. 5: Setting thermocouple correction factors in software

Thermocouple protection

Air flow shields (Fig. 4) protect the hot junctions of the thermocouples against mechanical damage which would affect their positioning.

Thermocouple calibration

Thermocouples designed for this type of system should be calibrated to ensure that any calibration errors can be offset by software to ensure consistent measurement (**Fig. 5**). If this is not done then when thermocouples are replaced it is possible to have errors of say 4 °C between sets (+ 2 °C on the old set of thermocouples, and - 2 °C on the new set), even with thermocouples which meet tolerances in BS60584. This would mean that a 4 °C difference in measured temperature is possible simply by renewing the thermocouples. If calibrated thermocouples are used and software is capable of offsetting the error, then all measurements are effectively 'zeroed' when a new set is fitted.

Thermal barrier design

Designing a profiling system that is light and easy for one person to use can be achieved by combining all the elements of the thermal profiling system into one unit. As can be seen from **Fig. 6** the data logger becomes an integral part of the system which is easily removed in one simple operation. It is held in position above the heat sink which allows the operator to remove the logger and download the information without having to break the barrier apart and unplug thermocouples etc. Again this ensures ease of use and helps to de-skill and speed up the operation.

Weight of the system is an important issue if one person is to be able to load and unload the system easily and carry it to a work station. A target weight of 12 kg was set to ensure that the system would meet these conditions.

Software

Objectives

The software designed for a surveying system should have two objectives; firstly as a tool the line operator can use quickly and efficiently for the scheduled trials, with the minimum of computer skills. Secondly as a powerful analysis tool from which QC technicians can obtain practical data on the process using SPC tools. These objectives can be further broken down:

- Design of software on two user levels for quality technician and line operators
- Easy categorisation of each furnace and product
- Simplify task of re-setting and downloading data logger
- Ability to set up tolerances and alarms for process parameters such as peak temperature reached, time at braze temperature, etc.
- Instant indication of process status (pass / fail) at conclusion of scheduled trials
- Ability to include thermocouple correction factors which can automatically be applied to the stored data on download from the data logger.

SPC functionality in software

The needs of the QC department can only be served if the software used with a surveying system has all the necessary SPC functions (Standard Deviation, Cp, Cpk, etc.), and can quickly and easily search through data files to perform the calculations on critical parameters such as maximum temperature, time at temperature etc.

Archiving data files

In order to search through a database of daily run data it is necessary firstly to store the data in a logical format. Experience has shown that data storage is generally haphazard and locating data files (paqfiles) is difficult. Therefore in designing software for a survey system it was decided that archiving of files should be automatic and that the directory structure on the hard drive of the computer should be to set up by furnace name (CAB line 1, etc.), then by product (radiator xyz etc.), and finally by date and time of the survey run. Saving data in this way, and saving it automatically, has several advantages:

- It saves the user the task of setting up the structure and then remembering exactly where to save the file.
- It makes it easier for the software to sort the data files in order to perform SPC calculations
- It allows easy comparison of the same product on different processes (furnaces) using SPC analysis techniques

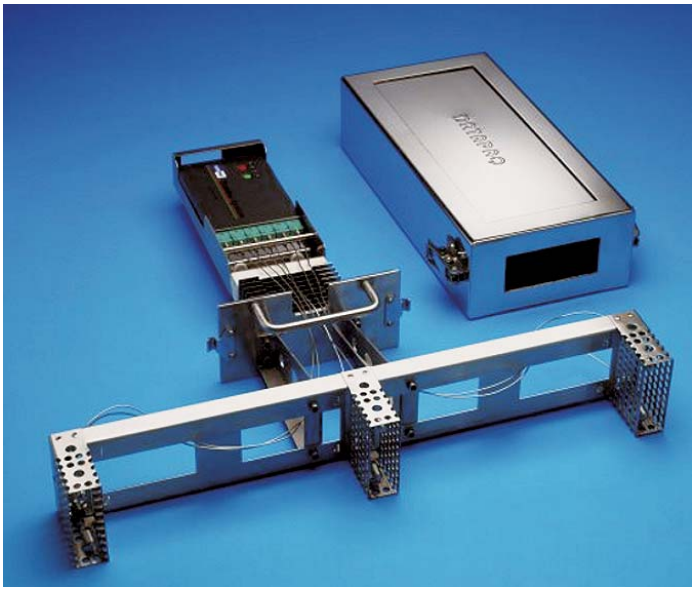

Fig. 6: Surveyor thermal barrier and arms

- logical archiving also makes it easier to carry out historic checks on process conditions for a specific product at a specific time should the customer request this.

Trend analysis

In designing the software it was decided to include the ability to analyze long term trends in process parameters such as increase or decrease in maximum temperature or time above braze temperature. This would be desirable as although past and present data may be within specification, the long term trend may be towards the upper or lower specification limits. This would give the user the ability to predict into the future and indicate if and when the process may go out of specification.

Operation of the CAB Survey system

- When the process is stable, the product has a good braze and meets all the physical specifications (burst tests, etc.), the survey system (**Fig. 7**) is passed through the furnace and the 'baseline' profile is established.
- Within the software, a technician then sets up tolerances around the baseline profile around critical parameters such as maximum temperature, time at brazing temperature, etc.
- Other baselines set up for additional products and furnaces.
- On a regular basis (daily, weekly, etc.) the operator will pass the survey system through the furnace, select the correct baseline and will be advised by the software as to whether the results are in or out of specification.
- After a number of runs have been made, enough data will be available for the technician to make a predictive analysis of the furnace and determine whether the trend is stable or whether there is a trend towards an out of tolerance condition.

Fig. 7: The CAB Surveyor system

- If there is a trend towards out of tolerance, action can be taken before product quality is affected.

Testing

Affect of furnace loading

Initial tests on the CAB System were carried at customers' plants in France, and UK. These tests were to determine the affect of furnace loading on process temperatures, as this would affect how users would set up the tolerances around the baseline profile.

In this trial the test furnace zone temperature and line speed were not changed, but Surveyor trials were run when the furnace was partially empty (light load) or fully loaded. The results indicated that differences of between 3 °C and 7 °C existed between lightly and fully loaded furnaces. This indicated that, whenever possible, the regular quality test should be carried out with the same loading conditions in order to get consistent results. If this is not possible then the tolerances should be widened to take loading into account.

Field trials

Actual trials under production conditions were carried out at customer plants in the UK, Spain and Germany to establish how the actual data gathered under production conditions could be interpreted (**Fig. 8**). These proved successful once the initial tolerances around the baseline survey had been set up. In one trial this took a little time to establish as the user became familiar with the equipment.

Trial durations

The duration of the trials were over periods of 9 days and 13 days and although the Surveyor was not run on a daily basis during the trials, enough information was obtained to give meaningful results

Trial results

The results indicated that in both sets of trials the process stayed within the set limits during the duration of the trial, and the overall Cpk (potential capability of a process to meet a specified standard) in terms of peak temperature and time above braze temperature, in both trials was above the acceptable norm of 1.00.

In the second trial enough data was built up for trend analysis to be carried out on the results. This indicated that results for peak temperature calculations were drifting towards the lower tolerance, but no alarm showed. However, results for time at braze temperature indicated that the process was likely to fall below the lower tolerance limit within a period of 4 days. If the tests had been extended then the quality technician would have been able determine the course of action to take to bring the process back into line.

Conclusion

Initial trials with the CAB Surveyor system indicate that it is possible for a new type of profiling system to be quickly and easily used on a regular basis for QC purposes and so ensure the process is within specification. Further, that combined with purpose built software, meaningful SPC information can be obtained that can assure customers the process will meet and exceed accepted norms, and also to give early warning of trends that may cause a process to go out of control.

Fig. 8: CAB Surveyor in trials at customer plants

ALUMINIUM 2006

Datapaq Ltd.
Hall 1 / Booth F46