

The Design and Operation of a Computer-Controlled Flow Box

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Introduction

ONE of the problems encountered during the computerisation of No. 6 machine at Dartford was the need for a flow box control system to replace the existing Hornbostel hole arrangement. The circumstances were such that we required a control system implemented by the computer program (DDC) and the facilities for bumpless transfer to an analog controller arrangement in the event of computer failure.

To attain reliability and simplicity, we limited our investigations to the manipulation of the stock and air pressure supply valves to effect automatic control. Our control objectives were—

1. The minimisation of level and total head variability.
2. The maintenance of stable control at all times.
3. The inclusion of efflux ratio control, in the computer controller, to reduce general variability and aid weight changes.

Simulation

We proceeded with an analog computer simulation based upon the flow box equations previously deduced by J. Mardon *et al.*⁽¹⁾ and P. A. A. Talvio.⁽²⁾ Owing to the lack of instrumentation on our papermachine at the time, we were compelled to deduce the constants for the analog computer equations by measuring the flow box and calculating the stock flow from a knowledge of the slice opening and total head. It was our intention to use the simulation to investigate alternative multi-loop three-term control systems to those developed by Mardon and Talvio.

We used a step input of stock flow as a disturbance in the simulation and overshoot plus settling time as a criterion for comparisons. After investigating 10 multi-loop control systems, the simulation results showed that a control system very similar to the one proposed by Talvio gave the best results,

Under the chairmanship of P. E. Wrist

whereas the system originally proposed by Mardon was the best and simplest alternative for use as an analog standby control system. We therefore decided to go ahead with—

1. Total head control by stock flow and level control by air pressure—for our standby control system.
2. A level controller cascading on to an air pressure controller and a total head controller cascading on to a stock flow control loop—for our computer control system.

The simulation predicted a 3:1 reduction in variability from the computer system compared with the standby system and about a 30:1 reduction in variability from either of the instrumented systems compared with the Hornbostel hole.

During the computerisation of No. 6 machine, the validity of our choice of flow box control systems was checked by R. Fletcher of Ferranti Automation Systems Division, using a digital simulation.

Results

Both of the control systems mentioned have now been in use for a year. Only a small reduction in total head variability could be attributed to the computer system compared with the standby system, although both of these systems were substantially better than the Hornbostel hole.

Tuning the cascaded loop computer control system was not easy and the controller parameters currently being used, pending further investigation, are only really suitable for the top three quarters of our normal total head operating range. Much difficulty was experienced while attempting to use the computer control system at machine startups. We have therefore tuned the standby control system to give a satisfactory response for machine start-ups, which also gives a reasonable response for steady running conditions. The procedure we currently use is to start up on standby control and switch to computer control as soon as the large start-up transients have disappeared.

We have experienced no problems while using our computer-controlled flow box during large basis weight changes. The level merely remains fairly steady, whereas the efflux ratio control ramps the total head.

Fig. 1 shows an example of total head/level responses during a combined machine speed and weight change.

Conclusions

Our flow box simulation work and subsequent operating experience has highlighted two main problem areas—

1. The necessity for very reliable control system hardware.
2. The necessity for wider investigations at the simulation stage.

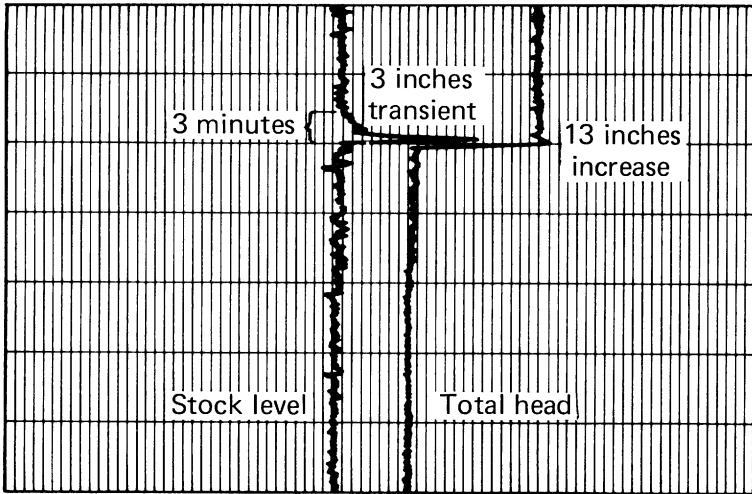


Fig. 1

Desirable improvements are—

1. More accurate values for flow box parameters.
2. Better representation of the dynamic characteristics of measurement and control hardware.
3. More realistic criterion for comparison of simulated control systems.

For example, a digital computer could be used to data log the measured flow into the flow box and statistical techniques employed to produce a 'noise model' of the flow. Then, using a digital simulation of the flow box, representative flow input disturbances could be applied to the various flow box control systems. A suitable criterion for controllability would then be the reduction of the slice flow variability.

References

1. Mardon, J., Monahan, R. E., Mehaffey, W. H. and Dahlin, E. B., 'A theoretical and experimental investigation into the stability and control of papermachine head boxes': *Paper & Timber (Finland)*, 1966, **48** (1), 3-14; (5), 301-303, 305-310
2. Talvio, P. A. A., 'A study of papermachine head box control systems with linear transfer functions' (IFAC Conference, London, June 1966)

Transcription of Discussion

Discussion

Dr L. A. Kirk As we at Manchester University have a similar kind of papermachine, I would be very interested to know the total cost of computerising your papermachine. In view of the papers we have heard on the exact extent to which computer control has been applied in industry, do you consider it worthwhile for our machine to be computer-controlled at this stage?

Mr S. Bauduin The total cost of the project, which extends over a three year period (until the end of 1970) is approximately £140 000, including—

Instrumentation and wiring	£30 000
Computer	£10 000
Ancillaries	£15 000
Personnel salaries, etc.	£85 000

Our machine is quite different from an industrial one, although time constants are nearly the same. We think that the approach to control problems will have to be the same. Besides, such a system is very convenient for training purposes.

Dr J. A. Robinson In the text, it is stated that the response of the model appears to be better than the theoretical response, but the theoretical response in Fig. 7 appears to be better.

Mr Bauduin Our paper states about Fig. 7 that ‘an explanation has not yet been found for the fact that the response of the full model appears at first sight to be better than the theoretical response’. Thus, the ‘theoretical’ curve shows a permanent deviation, whereas the ‘simulation’ (full model) curve does come back to the original signal level.

We have now found the answer: it lies in an ill-adapted coefficient in the model used for the ‘theoretical’ curve (polynomial division program).

In spite of that, we have still shown the two graphs (Fig. 7 and 8) to illustrate the difference between the one time constant model and the three time constant model.

Dr Robinson The only point is that it appears to be in the reverse order on the graph.

Dr D. Wahren You said that the effects of recirculation of whitewater could be ignored. Was this because you had a very high retention on the machine?

Mr Bauduin Yes, I think so. Most of our tests at that moment were done with kraft pulp. In fact, the model showed, at least for high frequency fluctuations, that it is still true for low retention stocks for regulation purposes.

A Speaker In talking about head box control systems, we should remember that machines in operation today range 30–35 in to high speed newsprint machines with widths of over 400 in. A variation between 1 in and 35 in is quite different from 400 in. I think it would be helpful if any speaker who was talking of a specific machine would give the range in which he was working.

A comment on whether to install a computer on the University of Manchester papermachine. We should remember that the Fourdrinier machine is now in the state of obsolescence and, with the new formers available, before anyone can put a computer on such a machine, he should consider carefully whether it is adaptable to the high speed machines that are likely to be used in the near future.

The Chairman We are starting up a new Fourdrinier machine in two weeks' time; I hope such machines are not as obsolete as this speaker suggests.

Mr N. C. Underwood Will the authors and committee consider a uniform set of units for the measurement of gains, frequencies and response functions so that the results presented in the transactions may be more directly compared?

The Chairman These are very good points that the authors should attempt to take care of in editing.

Mr A. J. Ward Would Mr Gunnarson like to indicate the difference in cost between his rapid response electrical system and the more conventional pneumatic approach?

Mr K. G. A. Gunnarson The total cost for an ASEA system depends on delivery time. The estimated price for a complete system, including complete dc drive (500 kW) for the fan pump, Roots blower with complete dc drive, dp cells, pneumatic reference device for the total head is about 20 000 dollars.

Discussion

Mr L. D. Edenborough We have now seen two examples in which Mr Jones uses the CONRAD system. It seems to me that perhaps the building block approach of which he has spoken is to some extent comparable with the small mill that cannot justify a large computer system, but wants to do something a little cleverer than is possible with conventional analog control systems, a comparison of these two approaches may be worthwhile. Could Mr Jones please attempt to contrast them from the technical and economic viewpoints?

Mr R. E. Jones Comparing and contrasting is rather a tall order, because it would take quite a long time to cover all the implications of the two techniques. What I will say is that the control strategies that we have used with a CONRAD package certainly could be implemented by analog modules. I think it would be up to the individual customer or systems engineer to decide on the relative costs of going to these two different methods of implementing control. I would point out that *behind* the CONRAD package is a central processor that can do much background work as well.

Dr N. K. Bridge We have heard a lot about head box control this morning and speakers have quoted in passing figures for the control that they can achieve. I wonder whether it might not be of use to people when they get back to their mills if they could have a consensus of opinion from the experts on the platform on how well a flow box might perform with a good controller. What sort of variations might be expected in total head on grade, also how fast should it be possible to change the head?

Dr D. B. Brewster I would like to comment on Dr Sanborn's paper. The head box is a good example of a process for which a mathematical model may be developed directly from physical laws. The advantage of this type of model over the black box empirical model is that there are generally fewer parameters that need to be determined experimentally by identification. Identification experiments tend to make production superintendents nervous, particularly on machines that are being pushed hard. One feature of the head box identification described by Dr Sanborn is that the pond level response is determined open loop—that is, with the analog level controller disconnected. Special care must therefore be taken to ensure that level control is not lost.

It is not necessary to perform the extensive identification described by Dr Sanborn if the valve behaviour is modelled. Dr Al-Shaikh at Westvaco did this and was able to identify the head box completely, using only one experiment with the head box pond level controller on control. A DDC algorithm was designed with the controller parameters being calculated through the

model. The validity of this approach became evident when the machine speed was changed by a factor of 2 and the automatic tuning worked perfectly.

The major problem in the Sanborn paper seemed to be the sluggish valve action that resulted in dead time. It would seem to be preferable to solve that problem mechanically.

Dr I. B. Sanborn The way we set up our system is in some respects rather cunning. We always left the analog control on when there was a mechanical failure in hardware between the computer and the head box or, if we wished to open the loop between one to the other, we always fell back on the controller. The net effect was that, as far as the head box was concerned, it was no particular problem to open loops in identification. The magnitudes of the upsets necessary in identification were in the order of 1–2 in water and this was in total head operating ranges of 50 in down to 20 in. In many instances, unless we told the operator we were making an identification, he never knew it took place.

In this particular instance, identification was not as upsetting as it might otherwise have been. This is not the case with basis weight moisture control, however, which causes a decided upset in the process. I agree that a little cleverness can avoid a lot of identification. In fact, as I pointed out during the discussion after my paper, we have developed means now by which, having identified the parameters at one particular operating point, we have calculated at all other points as well. We probably identify initially when we throw the loop, then vary very infrequently, perhaps once every six months or a year.

Mr W. D. Hoath My first question is how representative is this machine of the process efficiency found on full-scale machines? Do Ramaz *et al.* expect to modify the basic process design on those machines to improve the end product—in other words, do they intend to make major process changes linked with the computers to exploit its power and versatility?

We have heard quite a lot from Dr Smith and Dr Sanborn on the need to improve the process to achieve even better control, but have we anywhere achieved major improvement design of computer control? One suspects that possibly we have gone a little way towards this at Grove Mill, but I would like to know whether any contributions could be made to highlight whether we are able to achieve it.

Mr Bauduin I am not quite sure I understand the question, but I take it that you wonder whether our experimental machine is quite representative of

Discussion

an industrial one, as far as our computer project is concerned. We have already said that it is rather different from an industrial machine, but may I remind you that our project deals mainly with studying the principles of computer control. We might undertake a similar study on an industrial machine as a future project; for the time being, we do not really care about production cost or things like that. Therefore, we are not concerned with 'major process changes linked with the computer'.

The Chairman I would like to ask a question of the audience. Is there anyone who has the experience of designing new systems or making major modifications to existing systems and who have made major departures in design as a result of their process control work? In other words, have they changed the size of chests or eliminated chests or other equipment primarily for control purposes?

Mr I. McKnight I should like to comment mainly on Dr Smith's paper with a more detailed question to Dr Sanborn. I think my remarks follow on from those of Mr Hoath and the Chairman.

I wonder, if the Fourdrinier papermachine had not been invented 150 years ago, but just a few years ago, whether the flow box would have been a rather different piece of equipment. I suspect the designer would have produced a device rather like an extruding machine under careful flow control. I suspect also that the measurement of total head would have been scarcely considered. My point is to stress the measurement of flow as the major control parameter and to ask how this conception would have modified the mathematics.

We discussed the Chartham flow box in an earlier paper and there are other machines for which flow control is the main control parameter of the flow box. If a lid was put on this box, I am certain it would continue to run for a reasonable length of time under control without even a blower or level control. If the air cushion was then pared away, you would end up with a solid flow box. Surely, accurate flow control should give the correct answer at the breast roll.

My particular question to Dr Sanborn concerns the flow loop of his flow box scheme. He has created a slightly long-term flow control, whereby the slice is used as a giant slide valve. Now, flow control is a fully established practical technology, with even controllers being manufactured with fixed terms. It is generally accepted that the equal percentage valve gives the correct characteristics. I would like to ask whether this was taken into account when programming his computer to characterise his linear slice valve.

Dr Sanborn No, we have not; we have accepted the valve as it is, but some

of the gain calculations made simply take the change in the valve constant into account.

The Chairman I would like to draw the last questioner's attention to the fact that there has been quite a lot of experimental work of a rather substantial nature done with nozzle type head boxes without any air cushion in the system. In general, most people have found that, in order to eliminate pulsations causing high frequency disturbances to the flow arising from pumps, for example, it is necessary to have a dampening effect of the air chamber.