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Prepared discussion contribution

Basis Weight Control—Sub-Optimum Approach

W. T. WHIGHT, Empire Paper Mills and R. E. JONES, G.E.C.-A.E.I. Automation Ltd.

AUTOMATIC basis weight regulation on No. 1 fine paper machine at Empire Paper Mills has been achieved by using a substance gauge at the dry end, connected to a central control digital computer, this computer performing direct digital control (DDC) upon various areas of the papermachine.

The basis weight feedback control is a dead time algorithm, which acts upon the set point of the thick stock flow DDC loop.

A pseudo-random binary sequence (PRBS) trial was initially run in order to ascertain the process dynamics. Data collection of thick stock flow changes and corresponding basis weight fluctuations indicated that the process could be described accurately enough by a first order lag plus dead time. A flexible dead time algorithm was developed from this model by assigning a suitable single time constant and setting up a series of values of dead time and process gain in a 'look up' table.

This basis weight digital control program has an execution rate of approximately one quarter the transmission time taken for the first effects of changes in the thick stock control valve to be observed at the substance gauge.

Although the process time constant varies a little with the grade of paper in production, we felt an adequate controller could be constructed, based on a constant value. The dead time part of the model is tuned by using a 'look up' table of current thin stock (head box) flow and wire speed (the principal contributors to changes in process dead time) to determine the correct dead time parameters for the algorithm.

Similarly, the loop gain varies between grades and a further 'look up' table of substance and thick stock is used to extract the current gain parameter for the control loop.

We consider that the effect of this method of achieving basis weight regulation has been to produce about 90 per cent of the possible improvement that could be obtained by a full-scale system modelling exercise and development of an optimum algorithm. Closer system identification and control accuracy can be achieved only at a greater cost and with longer time for systems analysis.

Discussion

Mr H. B. Carter Would Mr Jolliff please clarify whether or not the Southern Kraft Division operator has some discretion on the head stock factor and carriage?

Mr C. C. Jolliff The operator enters the desired basis weight through a manual station. He enters the desired moisture content in the same way. In controlling refining, he ordinarily keeps control himself until the laboratory tests show paper properties to be within specifications. He then signals the computer to maintain refining at that level.

Dr I. B. Sanborn You mentioned that you have no moisture sensor before the size press. Is that correct?

Mr Jolliff We had a moisture sensor there, but not at the present time.

Dr Sanborn In essence, you predict the change that you have to make in your steam pressure to compensate for fibre changes?

Mr Jolliff That is correct.

Mr W. L. Daniel Has any consideration been given to the different refining effect obtained from refiners on light load from those on heavy load in the total load redistribution program?

Mr Jolliff No, as no difference in refining had been found.

Mr M. A. Keyes Initially, you did some work on the Georgetown installation that involved on-line measurement of wet end table flow patterns. Has this been incorporated in any control schemes?

Mr Jolliff All our controls are based on fact.

A Speaker You mentioned the Box & Jenkins method with the process parameters for basis control, but what methods were used to determine the model parameters used for the controller?

Mr Jolliff The parameters estimated by the Box & Jenkins method were minimising the variance and maximising the likelihood function.

Dr A. R. Farmer Please indicate the extent of the functions performed by the computers at the mills you mentioned. You refer to basis weight, moisture content and refiner control. In fact, what other functions does the computer perform?

Mr Jolliff The six computers installed in the Southern Kraft Division have a number of other tasks, but not all performed in any one mill. So far, we have used computer control on bleaching lines, lime kilns, multiple effect evaporators, recovery boilers and in the controls I have mentioned.

Mr R. E. Johnston In as much as the controllers suggested by the methods of Astrom and the methods of Box & Jenkins are almost the same controller —basically a dead time algorithm—it surprises me that no one has used any of the commercial units available for this purpose. Has anyone here had any experience for using them?

The Chairman This might tie in with a question that I wanted to ask Mr Jones—whether or not CONRAD included the facility for varying the dead time compensation automatically as the process dead time changes? Does the hardware offer the facility of automatically changing the parameter when the machine speed changes?

Mr Johnston No, it would have to be a manual change on the basis of a look-up table.

Dr Sanborn I should be pointed out that dead time in the papermachine does not correspond to an even number of sampling intervals. Hence, one must either truncate or round off when choosing the correct sample lag. With traversing gauges working on average basis weight, this can cause serious errors in dead time compensation. These errors seem to cause no serious problems of control on a practical basis. Thus, we have another illustration of a point that, though apparently important theoretically, is in fact not significant practically.

Would Mr Jolliff please comment on his remark that he needed to readjust the refiner controller each time he adjusted his stuff gate.

I presume because of this that you are unable to adjust the stock valve as frequently as once every 8 s.

Dr Farmer I should like to come back to the question I asked Mr Jolliff originally and his answer to it. Are facilities also provided for management information data processing or production scheduling? Please comment on the justification of the systems installed and the principal areas of pay-off.

Mr Jolliff We have not made a practice of printing out trend lags or other operator guides. Most of the installations have programs available for data collection, which are used as required. Our first installation in Georgetown was a research project of the New York office and did not have to be justified economically. We have had with that and subsequent installations attempted justification after the event because of very poor knowledge of the cost of running on and before the computer was installed. The only time measure of success I believe is the acceptance of computer control by management and ours continues to appropriate money for additional control computers.

Mr O. Alsholm Most of the DDC installations in U.S.A. and in Europe are equipped with almost complete analog back-up. There is no criticism in this statement, as it corresponds to the level of confidence we have achieved so far. On the other hand, our purpose is to make computer installations yield the most economical return possible. Analog back-up is expensive, thus the cheap 'limited' controllers used at Sittingbourne appeal to me, especially as I question the necessity of a complete bumpless transfer, if the computer isolates only a few times per year. Having available both Mr Keyes (who has been involved in most of the recent American DDC projects) and Mr Cyprus, it seems likely that we could get advanced comment on the matter of analog back-up in general, especially on the point of bumpless transfer to analog back-up. Not to be misunderstood, I would like to state that I do not mean the switch between computer control and manual back-up and vice versa.

The Chairman I am interested in CONRAD, which takes ten blocks to do basis weight control. How many words of storage are required for the block and what is the average number of blocks?

Mr R. E. Jones Ten blocks do the basis weight control. This includes, of course, the filtering operation I showed, which is using two of those and one to regulate the loop gain. On this particular installation we had a storage

allocation of 12 words per block of 12 bits each. We are working on a CONRAD package of somewhat greater power, perhaps taking 15 words of 18 bit length, but this will give greater facilities and a larger number of functions.

The Chairman I am sure that this aspect of programming to those involved in installations is recognised as a very important one, particularly this CONRAD approach and the one that Mr Alsholm has used. In Mr Jolliff's paper, there is reference to using machine speed as the manipulated variable for moisture control on a dryer-limited machine. Speed is a very important variable economically and I was rather concerned when he said that it could not be manipulated, because it requires a difficult model and the reason for this was that the head time changed when speed changed. I would like to question this point of view. For regulation purposes, the speed changes would not be great, so one would not expect the dead time to change very much. I consider that the major problem of manipulating speed is that the gain between the speed and the dependent variable moisture content is rather indeterminate; it can be either positive or negative, maybe even zero.

Mr Jolliff Our development group is at present finishing work on a program to maintain the papermachine at optimum conditions for the making of a grade of paper. This will include speed control, of course, but not specifically as a way of controlling moisture content.

Mr Keyes Two comments. One is about adjusting speed as an integral part of a moisture control system. Mr Robert Fritchie while at Albemarle Paper Co., Roanoke Rapids, N.C. implemented a system of this kind. It is particularly valuable for dryer-limited situations such as are encountered on linerboard machines.

My second point is a question for Mr Jolliff on the use of z-transforms for the design of a basis weight controller. As has been pointed out, use of the transforms in the case of dead time assumes that the dead time is an integral multiple of the sampling interval. Has anybody applied advanced or retarded z-transforms to basis weight control system design and, if so, what were the results?

Mr R. E. Jones If I understand the question, it is about the modified transform when the process dead time is not an integral number of sampling intervals. The way we have tackled this is to use the modified z-transform. One of the parameters in the string of blocks in my last figure is not unity, it is a parameter that we call M. The range of M is between nought and unity; its purpose is to handle the fractional part of the dead time.

Discussion

Dr Sanborn To control speed, we do not adjust machine speed for the control of sheet moisture content, but we do consider speed to be the most important variable affecting productivity. If computers are to pay for themselves, productivity must be increased. Hence, speed must be controlled if money is to be made. We have a machine, for example, that in certain circumstances is speed-limited; under other circumstances, it is drying-limited. In this case, we are monitoring the speed and steam valve opening on this machine. If they are both not at some specified maximum value, speed is automatically increased by 10–20 ft/min, provided the drive is capable of such an increase.