REDUCING CYCLE TIMES IN ROTATIONAL MOULDING – A CHALLENGE

R.J. Crawford, Dept. Mechanical Engineering, The Queens University of Belfast, Belfast BT9 5AH

Abstract

Ever since its inception, rotational moulding has been heralded as the moulding method for plastics that has great potential. And it is true that it offers many advantages over other moulding methods - stress-free products, inexpensive moulds, short lead times, no weld lines, no material wastage, etc. However, the thing that has always hampered the widespread growth of rotational moulding is long cycle times. The unique feature of rotational moulding is that both the mould and the plastic must be heated from room temperature up to the melting temperature of the plastic and then back to room temperature. This means that cycle times are measured in minutes rather than seconds.

If rotational moulding is ever to be a serious plastics processing method to be considered by designers alongside injection moulding and blow moulding then the challenge for the industry is to reduce cycle times. This paper will review the state-of-the-art in rotational moulding and identify what needs to be done if cycle times are to be reduced. Current moulding machine designs will be analysed and previous research work involving the use of enhanced heating and cooling methods, internal heating, pre-heated moulds and/or plastic, mould pressurisation, process simulation, etc will be assessed. Challenges will be set for material suppliers, mould manufacturers, machine designers, moulders and researchers in regard to what needs done if major reductions in cycle times are to be achieved in this industry.

The purpose of this paper is to initiate a fundamental review of the rotational moulding process. Action is needed urgently by all the key players in this industry if it is not to go down in history as the processing method that offered the greatest possibilities that were never realised.

Introduction

Like most moulding methods for plastics, rotational moulding has evolved from other technologies. Injection moulding owes its origins to metal die casting, blow moulding emerged from the glass blowing industry and rotational moulding has many similarities to early methods used to cast liquid slurries into ceramic pots. There should be no great concern about borrowing know-how from other technologies. However, it often means that no-one has taken time to consider, at a fundamental level, exactly what it is that one is trying to achieve. The evolutionary process in moulding often involves "fire-fighting". A problem is identified and a solution emerges to meet the short-term need. This is particularly true in cases where the technology advances in an industrial or commercial environment. The pressures of production schedules dictate that the "quick-fix" solution is the popular option. The next problem that arises may or may not be related to the previous one but its solution is regarded as an advance whereas in fact it may be compounding the problem. Eventually one reaches a point where it is impossible to improve things any further. At this point, the industry is locked into a complex tangle of short-term solutions, each of which were probably correct on their own but which in the long-term severely hamper the further development of the technology. That is the point where one has to be brave and go back to basics.

It is a bit like climbing a mountain. The person already on the mountain regularly meets problems which, using his skill and initiative, he overcomes in order to move forward. He can see the top of the mountain (or at least the sky!) and therefore he knows that generally he is moving in the correct direction. However, at some moment in time he may reach a point were he just cannot advance any further. He has not reached the top of the mountain and must be satisfied with enjoying the view from the point he has reached. If only he had gone back and looked at the mountain from a distance then he could well have seen that there is a straightforward route to the top on the other side of the mountain.

Rotational moulding can learn from this analogy. The early stages in the process development were relatively straightforward. Heat a shell-like, metal mould with a gas flame and it is possible to cause plastic to form a coating on the inside surface of the mould. Eventually it was decided that open gas flames are dirty, dangerous and are difficult to control. Thus, hot air ovens emerge. They are much less efficient but they portray a cleaner image. Then one gradually adds computers to control the oven, statistical process control software to monitor variables and sophisticated cooling methods in involving air, water mist, fine sprays, etc. The original moulds were very simple and were perhaps manufactured by the moulder or a local DIY enthusiast. When the professional tool makers came on the scene, their terms of reference were already defined in regard to mould configuration, costs, etc. Over the years they introduce modest advances to make life easier for the moulder but at no stage are they regarded as being central to the development of the process.

The material suppliers are also regarded as having a support role. The moulders set the parameters in terms of the demands placed on the material. The material suppliers make valiant efforts to meet the required specifications but the high temperatures in the oven, the long heating cycles and the long cooling cycles severely restrict what they can offer. Hence, the industry is hampered by the lack of commercial resins capable of being rotomoulded.

So where has the industry got to today? Is it nearing the end of a cul-de-sac? What are the goals for the rotational moulding industry? Does it have a strategy to reach there? This paper addresses some of the key issues and sets a challenge to the industry. How will rotational moulding compete in the global moulding marketplace in the next century?

The needs of the industry

The rotational moulding industry is an enigma. The moulding technique has to be the least sophisticated of any section of the polymer processing industry. And yet the rotomoulding industry has some of the most inventive, ingenious people that you could find anywhere. Cynics might say that they have to be imaginative and creative to survive whilst using such crude processing methodologies. The truth is that rotational moulding is a challenging technology which more than any other allows the human factor to contribute to the full extent of its capability. The moulder can understand what is happening throughout the process. He can relate to this and control it. He can be imaginative in terms of creating complex shapes, perhaps multi-layered and he can make major changes to shape, material distribution, etc without altering the mould. This can be an extremely rewarding experience. The rotational moulding industry is thus fortunate to have attracted some of the most talented engineers and designers. One only has to look at some of the products that are moulded and one has to marvel at their skills.

But whilst one can rejoice in the success of the industry as a result of these talented people, there is also a feeling of sadness when one considers what might have been achieved if the technology of the process was improved. If only they had access to better heating methods, better cooling methods, better process control, more materials, better quality moulds, etc.

A few years ago the Association of Rotational Moulders (ARM) conducted a survey of the industry to establish what it perceived as its major needs (1). Of the top five items listed, the fifth was a plea for new materials and three of the top four related to reducing cycle time. It should be clear to anyone inside or outside this sector that a major reduction in cycles times must be achieved if rotational moulding is to compete seriously with other moulding technologies in the next century. This has to be the major challenge for everyone associated with this industry. It is highly likely that a significant reduction (x2, x4?) in cycle times would change the whole nature of rotational moulding. Things that are considered impossible at present, suddenly become possible. New materials may become readily available, process control becomes easier, product properties are enhanced and so on.

Reducing cycle times

When making a hollow plastic article in one piece, the basic requirement is to soften the plastic and cause it to take up the desired shape. Current rotational moulding methods can achieve this, as can injection moulding, blow moulding and thermoforming techniques. Are there other possibilities that have not yet been considered? Twenty years ago, lost core injection moulding was unheard of and yet today it is a major part of the automotive manufacturing industry. Rapid prototyping methods based on stereo lithography, fused deposition, laser sintering and so on are exciting new concepts that one day may be able to produce functional articles at short cycle times. One wonders what new technologies will emerge in the next twenty years.

However, even without being too ambitious it may be possible to do things with the current basic rotational moulding principle. At present the cycle times are many minutes because the mould and powder start at approximately 20 degrees C (68 degrees F). The mould is then heated to, typically, 250 degrees C (482 degrees F) in an oven at 350 degrees C (662 degrees F) in order to impart sufficient fluidity to the plastic. Everything must then be returned to ambient room temperature to facilitate ejection. There are many obvious questions that arise:

Could the plastic be heated without the need to heat the oven and the mould? Recent research has shown that the machine arm and the mould consume almost 90 percent of the thermal energy put into the system (2).

Could the mould be heated without the oven in order to provide more efficient direct heat transfer to the plastic? Jacketed moulds have been used commercially and electrically heated moulds are being developed (3,4) but can these be engineered to meet the heavy demands of the production environment? Infra-red machines have had some success, so are there other possibilities?

What would be the benefits of pre-heating the mould and the plastic resin? Preliminary research indicates that significant benefits are there to be taken.

What would be the advantages of internal heating (5), either throughout the heating cycle or during the relatively slow sintering stage? Heating of the material from one side only does not make sense if internal heating can be engineered.

Can the advantages of mould pressurisation (6) be used in an industrial environment? This speeds up sintering so that shorter oven times are possible.

Can internal cooling be engineered to provide faster cooling cycles? The big advantage of this is the provision of balanced, symmetrical thermal gradients so that warpage problems are alleviated (7).

Can moulds be designed to permit controlled pressure build-up during the cooling phase? This keeps the plastic in contact with the metal mould to provide faster, controlled cooling (7).

Is full biaxial rotation needed in rotational moulding? If not then services to and from the mould become easier.

Are machine concepts other than the carousel design likely to facilitate faster cycle times? The continual heating and cooling of the oven is inefficient. If it could be kept at its working temperature then the overall efficiency and performance of the process could be improved.

Can material characteristics be altered to enhance heat transfer? This may be a long way in the future, but improved thermal conductivity of plastics could be advantageous in many processing sectors.

Can materials be created or modified whereby morphology is more uniform and predictable and less dependent on, for example, cooling rates?

Can shear be introduced into the material? The absence of stresses during rotational moulding is often seen as an advantage but some stress would help to form the shape and consolidate the material.

Can mould materials and design, and/or surface characteristics be changed to improve heat transfer? The use of ribs and surface finish has been explored but the advantages have not yet been fully realised.

Could vibrations be imparted to the plastic powder/melt? This could induce frictional heating, help to remove bubbles, promote more uniform wall thickness distribution and perhaps reduce cycle times.

The way forward

At the present time there is a greater research interest in rotational moulding than there has been at any time in the past. More material suppliers than ever are taking notice of this sector due to its impressive steady growth. This is encouraging because their resources and competitive spirit will force the pace of change. Machinery and mould manufacturers are continuing their steady output of enhancements and there are signs of some very innovative ideas emerging. Rotational moulding is gaining respectability in the academic research communities and every year new institutions are developing an interest in the technology. This is highly desirable because a critical mass of research and development effort has not yet been achieved.

However, one cannot help having a slight concern that whilst all this effort and input is commendable, it is not co-ordinated. There is a danger that independent research and development workers will tackle problems that they have identified and we are in the situation referred to at the beginning of this paper. Individual problems are solved and represent a step forward in the direction everyone appears to be going - but is it the right direction? As an example, for years the industry was trying to get better and better methods to control the temperature in the oven before it realised that this is the wrong temperature to be controlling. Everyone in the industry now accepts that it is much more important to monitor and control the temperature of the air inside the mould (8).

In order to focus attention on a particular problem such as cycle time reduction, the industry through ARM or SPE or both needs to develop a strategy to promote and co-ordinate research on the chosen topic. It should not be left to individual companies or researchers to decide what the priorities are. If it is decided that cycle time reduction is the single most important problem to be overcome then a number of approaches could be taken:

(a) There could be a Managed Programme of research in this area. A call for research proposals from individual researchers or companies or preferably consortiums should be made. Research funds would then be allocated on a competitive basis to the proposals that appear to have the best chance of success.

(b) A Research Competition could be launched. ARM and/or SPE should set up a small committee to define a target cycle time for a one piece, hollow plastic moulding. The specification would define the wall thickness of the plastic product, typical surface area and so on. The first person or company or research institution to demonstrate that this product could be moulded in less than a specified cycle time would receive a significant cash prize. The target cycle time should be very demanding and there should be no restrictions on the type of technology that emerges. This would encourage novelty as well as enhancements of existing methodologies. It could be that the specification is defined in terms of product performance so that new material developments could be a possible solution. It is an unfortunate fact that new materials are difficult to develop for rotomoulding because of the long cycle times. However, if cycle times can be halved or reduced to a quarter of their current values then whole new possibilities are opened up.

The prize money would of course need to be sufficiently high to engage the interest of many researchers, including some large companies. This approach of utilising a Research Competition has worked well in a number of sectors and has the advantage of attracting publicity to the sector. There is also the advantage that the problem gets solved at a fraction of the cost of funding many projects, some of which yield little or nothing.

Conclusions

Rotational moulding is a unique manufacturing method for the creation of one-piece hollow plastic articles. Complex, stress-free mouldings can be produced but a major drawback is the fact that cycle times are very long.

The reduction of cycle times has to be the most important challenge facing the rotational moulding industry. If one could achieve cycle times of one quarter of those currently obtained then one has the opportunity to re-think the whole industry. New market sectors become viable due to improved economics and production rates. New materials will be available due to the lower thermal demands. Process control becomes easier and product quality is enhanced. In order to achieve these objectives a co-ordinated research effort is needed. This has to be led by organisations such as ARM and/or SPE in order to utilise their membership to define the problem, agree a strategy for its solution and provide the resources needed to achieve an urgent mobilisation of the necessary research and development effort.

References

1. Crawford,R.J “Future Developments in Rotational Moulding”, ROTATION, vol IV, Issue 1 (1995) pp12-18.

2. Attaran,T., Wright,E.J. and Crawford,R.J “Computer Modelling of the Rotational Moulding Process”, SPE ANTEC, Toronto, May (1997) pp3210-3215.

3. Wytkin,A “CMT – Composite Mould Technology for Rotational Moulding”, ARM Fall Conference, Oakbrook, Chicago, October (1997).

4. Wytkin,A “A New Rotational Moulding System – CMT” ROTATION, vol VI, Issue 3 (1997) pp30-32.

5. Sun,D.W and Crawford,R.T “Effect of Internal Heating during Rotational Moulding of Plastics”, Polym. Eng. Sc., vol 33, No 3 (1993) pp132-139.

6. Spence, A.G and Crawford,R.J “Removal of Pin-holes and Bubbles from Rotationally Moulded Products”, Proc. Inst. Mech. Eng., Part B, J. Eng. Man., vol 210, (1996) pp 521-533.

7. O’Neill, S “New Mould Design to Enhance Cooling During Rotational Moulding”, ARM Fall Conference, Oakbrook, Chicago, October (1997).

8. Crawford,R.J and Nugent,P.J “A New Process Control System for Rotational Moulding”, Plastics, Rubber and Composites, Proc. And Applic., 17 (1992),pp23-31