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13939

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ID/WG.137/31
18 September 1972

Original: ENGLISH

United Nations Industrial Development Organization

Symposium on the Development of the Plastics
Fabrication Industry in Latin America

Bogotà, Colombia, 1 November - 1 December 1972

# ROTATIONAL MOULDING 1/

by


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id.72-5959

The machinery and equipment designed for the rotational moulding will be suitable for moulding, without exerting any pressure, open and closed, seamless hollow parts of more than 10.000 litres in volume. For this purpose all thermoplastic materials, except polyproylene, can be used and most recently also the monomeric nylon 6 with much success. After referring to the processing developments you will find on introduction into the products which are feasible by rotational moulding.

The rotational moulding process is all the more of interest as relatively low investment and nearly no costs for wages will be involved. In large parts, the raw materials will make up to 80 to 90 percent of the total costs involved. The rotational moulding process will become more and more interesting with every wage increase.

The moulds used will be of metal of closed design, operating without any pressure and are rotating around mutually perpendicular axes. The rotating speed is below 30 rpm; in general there will be no centrifugal forces.

Both pasty plastic materials and polymeric plastic powder can be used. The processing of monomeric lactam for moulding nylon hollow parts has been most successful recently since the monomeric materials are less than 50 percent of the costs involved in nylon pellets or nylon powder.

The melting temperature for polymeric powder is in general from 300°C to 450°C. By heating and cooling the mould, which is rotating around two axis, the plastic material will be melting and is cooling down afterwards. The produced mouldings are practically free from any stress nor tension. For heating, air, oil or direct firing will be used. The rotational moulding machines of latest design are operating automatically and they will also be set and controlled automatically.

For hot air machines single wall moulds will be used, whereas the moulds for liquid machines are double walled. The hot air machine allows to reach temperatures above 300°C, but its precision in maintaining the values set for heating or cooling by water and air, will be limited. Precision is by far above by the liquid heated machinery where temperatures upto 300°C will practically do for the processing of all thermoplastics. In principle, it will be possible to manufacture rotational moulding machines, which may operate either with hot air or oil, allowing in this way to use single wall moulds for try-out and to install double wall moulds only afterwards for production after the product gives entire satisfaction.

For the anionic polymerization, the monomeric liquid material of a viscosity like water, will be supplied into the mould cavity and during the heating operation, the polymerizing process takes place at the same time as the moulding of the hollow part in one operation and with short cycle times. In this way fuel tanks of more than 2000 l in volume have been produced in Germany at costs, which are by far below steel tanks.

In addition the weight of plastic tanks is by 80 percent below that of steel tanks and the design of the product need not take into consideration the rules for vacuum forming and blow moulding. Furthermore, such seamless design had never been possible before by any other method.

The liquid heated rotational moulding machines allow furthermore to mould sandwich designs without stopping the operations, comprising foamed materials with massive layers inside or in between.

As only the processing temperatures make a difference in the moulding of hollow parts of nylon 6 and other thermoplastics, a special mould design will allow to supply monomeric nylon into a mould, which is meant for moulding parts such as tanks demanding special resistance against solvents, fuel oil or similar, or to supply polyethylene powder into the same mould for moulding containers for storing and transporting acids and alkaline materials.

The cost estimates, which have been made up in particular for hollow parts above 1000 litres in volume, have shown quite clearly that the manufacturing costs are below those involved in parts of glass fibre polyethylene. Such a part of 2000 litres can be seen on Fig. 1. In front you will see the polymerizing and metoring plant for monomeric nylon 6, the rotatioanal moulding machine is in the back.

The Fig. 2 shows the heating and cooling system in the mould of a liquid heated rotational moulding machine, model MRA. The inert gas can be supplied into the mould cavity through the rotary arm at "a" in horizontal direction through the crankshaft during the rotating operation; this will contribute to keep the moulding attached to the inside wall of the mould cavity, especially during the cooling and after shrinkage where difficult materials are concerned.

The heating medium (synthetic oil) will be supplied at the left side through bushings at "b". After transmitting its heat through the mould cavity wall, the oil will flow back on the same way and leaves at "c". As the heat transmission coefficient of fluids is above that of air, the MRA machinery has been recognized all over the world (by nearly 60 machines) for itsclose temperature control and its economy which are both superior to the hot air system.

In general, the cycle times are shorter for small parts when hot air machines are used. As you will see on Fig. 3, these hot air machines are running in principle on two arms, one of which is turning around the axis and the other one inside the axis.

The maximum cylindrical diameter and height of the finished product results from a and b.

The Fig. 4 shows such a hot air rotary carrousel machine, system McNeil/Krauss-Maffei.

For medium-sized articles of lower quantities, the automatic air machines of the model LRA of SINGLE or DUPLEX design have also stood all tests most successfully (Fig. 5). In this case one or two driven carriages with the moulds will pass through one heating station and two cooling stations The dimensions of this large hot air machine can be seen on Table 1. (Fig. 6)

Fig. 7
The Table 2/gives the overall dimensions of the liquid heated machines. In particular the dimensions above 3000 liters are most interesting, this means the model MRA 3 and above are being used most successfully.

Fig. 8
The Table 3/will give you a certain reference as to the use of the three models of rotational moulding machines as described. The double wall design of the moulds for MRA machinery can be seen on Fig. 9 (6) You will see quite clearly how the spacers are holding the corresponding two steel walls. The mould is nearly free from all pressure both in the cavity, where the product will be moulded, and between the walls. As you will also see from Fig. 6, the design of these moulds allows to install automatic mould opening and closing equipment as these are not exposed to heat, contrary to the hot air machines. This is a current equipment where compressed air or nitrogene will be supplied through the rotating arm.

The so-called model RT 5 - directly fired rotational moulding machine - is specially designed for moulding PVC balls or toys. Such a machine can be seen on Fig. 10 (7) By means of a few moulds, the machine will be suitable for producing with utmost precision more than 300 balls/h on a space of 4,5 sq.m.

The machine can be operated by one man, who will have to take out the moulded balls and do the metering into the moulds. The complete operation is automatic. The advantages of this machino are that the two rotary axis will meet exactly in the centre of the products in order to assure uniform wall thickness, but minimum quantity of raw material. The machines of this type have stood all competition in Germany and abroad.

As regards the use of our plants for the anionic polymerization of monomeric nylon 6, you will see on the Fig. 11 (8) and 12 (9) the plant as it has been arranged by one of the most important steel companies. In many cases the metering unit (h) will be placed on the drive (g) of the rotational moulding machines; for the production of serial products such as 2000 liter fuel tanks, the complete operation is automatic, including the metering operation for several times of the monomeric liquids by means of a tiltable arm. In the end the machine will go into stop position so that the operator will only have to take off the finished product. No matter of the volume concerned, tanks of several thousand liters volume can be produced within less than 20 minutes.

For the rotational moulding process not the volume of the moulding will be decisive for the cycle time, but only the wall thickness. The cycle time will be just the same for fisher net balls of 9 mm wall thickness and 2000 liter containers of 9 mm wall thickness.

On Fig. 12 (9) you will see a lateral arrangement of the metering plant.

The Fig. 13 (10) will show unbreakable light globes of latest design, which are made of plastic instead of glass. The special rotational moulding machine of our make will be able to produce 20 pieces each hour of these parts.

On Fig. 14 (10 a) you will see light globes of polystyrene which are made of multi-colour pellets; these products are most popular and provide for perfect heat elimination.

The Fig. 15 (11) shows such a rotational moulding machine of special design with five rotary stations, where all stations are arranged this way that the two rotary axis will coincide with the centre of the product. This machine is beyond any competition for moulding light globes in particular in ball form. The process takes place under inert gas and by the use of vacuum and compressed air in accordance with the demands by the used raw material.

The cycle time for light globes is below 15 minutes and it will thus be possible to produce more than 20 light-globes each hour up to 300 mm in diameter, which will not need any subsequent finishing.

The Fig. 16(12) shows a mould for 300 liter transport containers and picture no. 17(13) shows the product from this mould, which has already been placed into a grid box. Every 32 to 36 minutes one each container of 300 to 1000 liters volume will leave the mould and the operator must not rest at the machine during this cycle time. During this half an hour, the operator can be occupied with the completion of the container.

The Fig. 18(14) shows the universal use of the rotational moulding process. For a 1000 liter container it will be use to mould in one piece at the same time the flange and the 90° socket just like covers at the same time with the moulding itself.

The Fig. 19(15) shows the production of 18 transport and storage tanks of 2500 liters in volume and of nylon 6, production obtained in approx. 6,5 hours.

The use of polystyrene is becoming more and more interesting for the production of furniture parts by the rotational moulding process. Fig. 20(16) Contrary to the usual furniture parts, the rotational moulded furniture will neither be plane on the surface and cold when touching it, nor of low wall thickness as usually previously. There will be concerned hollow parts which will be of up to 50 mm at the thinnest place; there is a most comfortable feeling and they can be varnished in various colours, unless the raw materials have already been coloured before. The cycle time is from 7 to 10 minutes according to wall thickness and melt index of the processed polystyrene or similar of nylon 6.

Another most interesting and modern rotational moulded furniture part is shown on Fig. 20 a, (16 a) a much more economic way than glass fibre in the past.

Fig. 21 (17) shows a multi-purpose double walled boat (with motor, for rowing or sailing), which has been produced by the rotational moulding process. 22 (17 a) 23 (17b) Rotational moulded parts like these boats, have been tested for months under most keen conditions, but they stood all tests.

Fig. 24 (17c) and Fig. 25 (17 d). The manufacturing costsof rotational moulded parts are practically a matter of the raw material costs and the rotational moulding process of such holiday products will be successful in future also for large dimensions and most attractive design. This boat can be produced within approx. 43 minutes cycle time; it is of 50 kg weight; it is double walled and PE foam will prevent it from going down. Single wall boats can also be moulded.

The variation and the universal use of the rotational moulding process can also be seen on the picture no. 26 (18) this is a packaging palette which will be most promising on the market for transportation of food and in cooling houses. This part will prove that not only ball like open and closed parts can be rotational moulded.

The Fig. no. 27 (19) shows the possibility to mould today most difficult threads with key locks which can be moulded most reliably owing to the swivel equipment on the MRA machinery.

Fig. 28: (19a) A well reinforced bottom construction of a self-bearing transport and storage container 4000 liters of HD PE;

Fig. 29: (19b) shows the product,

Fig. 30: (19c) the mould

Fig. 31: A fur-ture design which is most resistant to torsion like the shown boat (19d)

Fig. 32: (19e) Sandwich wall with foam and/or glass fibre.

The Fig. 33 (20) shows the production of approx. 10.000 liter tanks on the rotational moulding machine model MRA 4.

On Fig. 34 (21) you can see the design of seamless, rotational moulded bath (wet) cabins or similar of approx. 2 meter-s in height, which are ready for installation. By a sandwich design of such parts, consisting of a solid outside skin of high-density polyethylene and of foamed polyethylene inside, even large parts, may be caravans or small houses like cells, can probably be rotational moulded in future.

The picture no 35 (22) shows the rotational moulding works of one of the most important steel companies in Europe, Messrs. Thyssen, for the production of 2000 liter fuel tanks of nylon 6. These products are already less expensive than steel tanks; for this reason they gave up the latter ones as soon as the rotational moulding works started operation.

Procedure of Rotational Moulding

a) Monomers as Basic Material

In the metering and polymerizing plant, the reactive compound, 98,7 percent Epsylon caprolactam, will be produced within shortest time by mixing a few hundred grammes of activator and catalyst into the monomeric basic material (between 50 to 200 kg/min.). This compound with a viscosity similar to water at a temperature of 120°C will be fet into the rotational mould by means of a special feed pipe. After completion of the feeding operation of less than one minute, the mould, which is automatically controlled, will start rotation and both the polymerizing of the material and the moulding of the product will take place simultaneously.

At first a pool of melted material is gathering at the lowest end of the rotational mould. With the viscosity increasing with the polymerizing operation, the material will be spread over the inside mould surface and each rotation of the mould around two axes causes a layer of the melted material to be deposited on the accurately heated inside mould wall. The speed ratio of the rotation for the two axes, is top secret by the moulders and must be ascertained before being set in the automatic programming of the machine for production purposes. In general, it will take 4 to 6 parts for finding out the best speed ratio. These values will then be taken up into the automatic programme which will then run automatically for 10 to 15.000 serial parts/year.

For moulding large parts, 10 rpm will in general not be surpassed in the primary axis and in the secondary axis.

At the end of the polymerizing operation of approx. three minutes each and the corresponding metering, the cooling will start automatically by maintaining the mould rotation. The mould temperature is approx. 175°C and the temperature for unmoulding is 140°C.

The process is most interesting and economic as practically one single t of 25° is taken to and fro. In this case the moulding of nylon 6 of up to 2 meters in length will be of stable shape as to allow to unmould it at 140°C. Due to the poor thermal conductivity of the nylon 6, this temperature is of interest as it is maintained for a long time. As some of our customers do, various shapes of the moulding can be obtained by blowing compressed air of approx. 1 to 1,5 kp/$cm^2$ into the hot moulding by means of a special equipment. This process can simply be named "rotational polymerization blowing" and it allows to mould special shapes for example for reinforcement, without affecting the mould costs nor increasing the cycle time. This most promising procedure is only at its very beginning.

The trend is now going over to high wall thickness of approx. 10 to 12 mm for nylon 6 and 20 mm for very large polyethylene tanks; in this case only a quantity of the liquid monomer corresponding to 2 mm wall thickness, can be introduced into the mould; otherwise the wall thickness will be inaccurate.

The mouldings of wall thickness below 4 to 5 mm, should be caused to absorb approx. 1,6 to 2 percent water in hot water of 70°, or saturated steam of 100° or by storing them in the open air during several weeks; in this way the nylon 6 products will become practically indestructible. For higher wall thickness above 6 mm, such conditioning will no longer be necessary under normal temperatures as it takes place only in the surface of the wall.

b) Powdered Polymers

The amount of powder required to make a particular item with a given wall thickness, is fed into the open mould. This is followed by the automatic rotation around two axes by simply pushing on a button.

For moulding threads or other difficult particularities, the rotational moulding machine comprises the automatic swivel device in order to avoid forming of bridges or other inconveniences in special moulding shapes.

The powder of grain size from 300 to 1000 mμ is rolling along the mould surface and flows by its gravity towards the deepest end of the mould. After completion of the fusion, the heating of the mould by pressure and sucking pumps, which have been dimensioned under consideration of the requirements by the process, will be automatically switched off. Without stopping the rotational motions, the hot oil will be replaced by the cold oil, which is pressing the hot oil out of the mould. The heat from the mould wall and from the product will be taken off by means of the oil, which will be cooled down in a cooler.

The advantage is that the precisely adjusted and controlled temperature will cause no thermal degradation to the material. In addition, nitrogen or vacuum can be fed where more sensible materials will be processed.

At the place where you would like to mould a manhole for example, the double wall design changes over into a single wall, where no melting will take place and the moulded product will in this way need practically no finishing afterwards. Such a zone, which is not heated, can also be provided for between the cover and the product itself, in order to allow the moulding of parts with the cover or double mouldings. As the use of high density polyethylene is becoming more and more current as its properties are most valuable with respect to resistance to cold and weather, notch strength and rigidity, the use of the rotational moulding machine of the model MRA turned out to be most successful in particular for processing high-density polyethylene.

These material qualities demand carefully controlled cooling unless there will be a lot of waste as with the hot air machinery. The cooling system in the MRA machinery will allow for slow cooling in the beginning and faster cooling afterwards. For this purpose, the programmed operation of the MRA machines will be of advantage as at the end of the cooling operation, they will go automatically into unmoulding position where the moulds will open automatically by a pneumatic system.

Our customers are most proud of their output, which is free from any waste.

For moulding sandwich walls consisting of high-density polyethylene of a few mms and of foamed high-density polyethylene of 12 mms and more with a density of approx. 0,3 kg/ m3, the moulds will be equipped with feed hoppers. The first rate for the outside skin will be supplied into the open mould. After this first quantity is melted for the first layer, the material of the first feed hopper will be fed automatically by means of an automatic valve. This latter material includes some foaming agent and will produce the central sandwich layer; as soon as this is melted, the last feed hopper will be discharged without stopping the rotation in order to produce, if desired, the inside skin.

The highly stabilized and costly materials will only be of interest for the outside skin which is exposed to special stress. As this matter material will increase the safety stability for example against UV and sun rays, the unstabilized material can be used for and fed by the feed hopper for the sandwich layer in between.

In this way it will also be possible to mould layers consisting of polyethylene and powdered polymeric nylon by the use of foamed polyethylene as this foamed layer will compensate the different shrinkage by the various materials. In this way it will also be possible to combine thermoplastic materials of different qualities.

Profitability of the Rotational Moulding Process:

For considering the economy of this process, the following should not be left out of view:

The invbestment required for the rotary machines and the moulds, are only approx. 25 to 30 percent those required by different plastic processing methods for the production of parts up to 1000 l in volume. As the manufacturing costs comprise up to 30 % for depreciation, the costs each hour are considerably lower for the rotational moulding process. According to the type and the sizes of the mouldings, a profit is given sometimes by a few thousands parts already.

For products above 1000 l contents up to 10.000 l and more there is no other process in competition with rotational moulding.

Furthermore, the rotational moulding process allows to male full use of the raw material as there is no loss by cuttings or flashing. Wall thickness may be varying without changing the mould. The fed quantity of the raw material will determine the wall thickness.

As the complete procedure develops automatically, there will be no costs for wages during the operation of the rotational moulding machine, except for unmoulding and metering.

As regards the tolerances, detailed statements can be found in the VDI directives.

With respect to profitability, it should be taken into account that the rotational moulding machine of the model MRA, will be amortized within one or two years provided the product has been designed accordingly and legislation will allow to do so.

In addition a market will be able to accept 5000 to 10.000 parts a year more easily than much more as obtained from a blow moulding machine operating in three shifts.

The rotational moulding process will become more and more of interest with every wage increase.

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ID/WG.137/31 SUMMARY
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Original: ENGLISH

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SUMMARY

# ROTATIONAL MOULDING 1/

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Because of low investment and labour costs rotational moulding can be regarded as a process in which raw-material costs embody 80-90% of total costs. The process, suitable for hollow articles of up to more than 10 litres, is based upon charging the raw-material, in the form of powder, paste or as in the case of Nylon 6 the monomer, into a single or double-walled mould which is rotated as below 30 r.p.m. around two, mutually perpendicular axes.

Hot air, oil or direct firing can be used for heating the mould and air or water for cooling.

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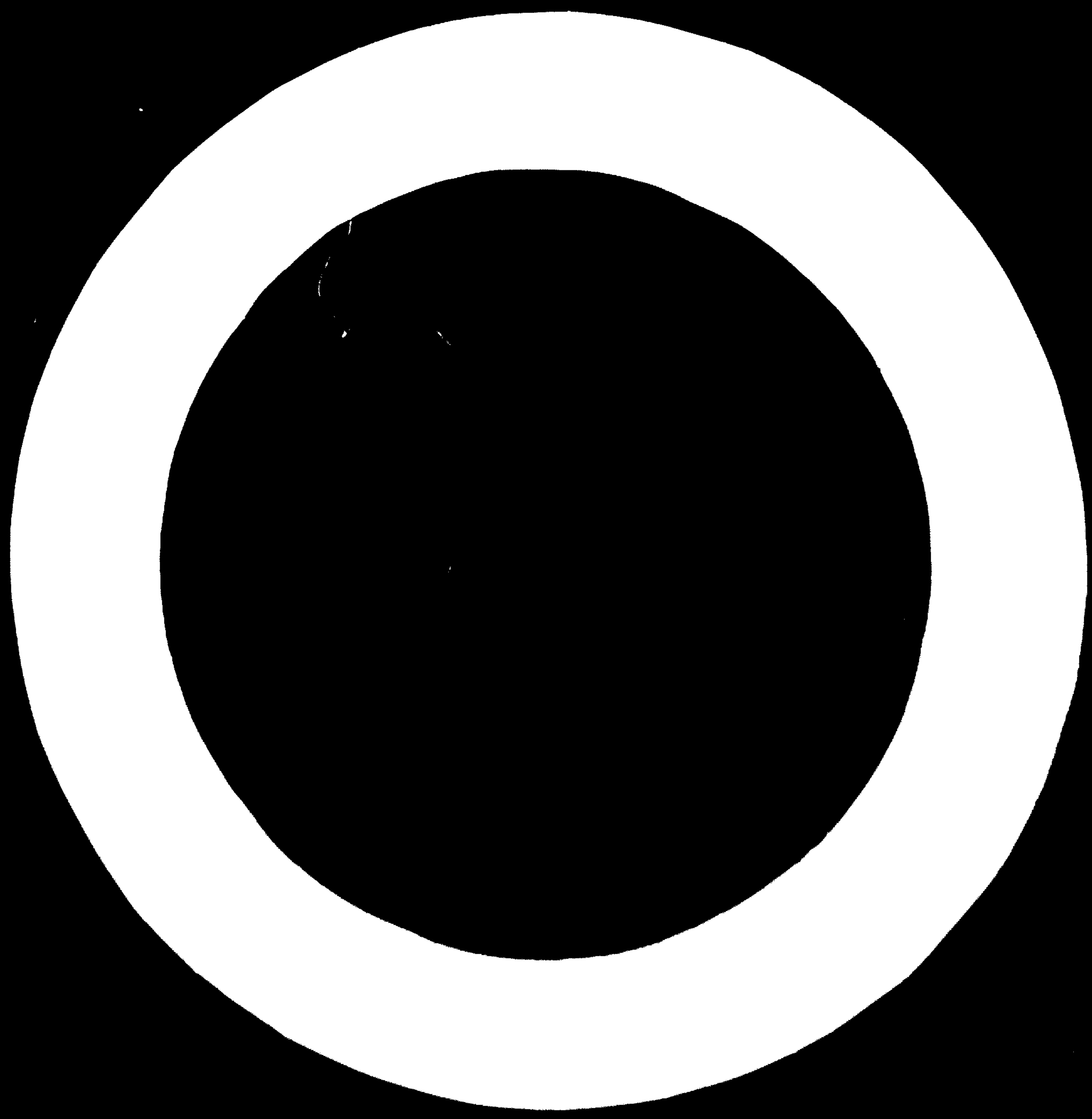
id.72-5691



While the process can be employed for all thermoplastics except polypropylene it is particularly suitable for the in-situ polymerization and casting of ω-caprolactam, which in the monemeric state costs less than 50% than Nylon 6 pellets.

A hot air rotary carousel machine, a double-wall machine embodying means for automatic mould opening and closing and a direct fired machine for PVC articles are described.

Cycle times, embodying for example one heating stage and two cooling stages, are conditioned solely by wall thickness. Articles produced by this process may range from transportation and storage tanks, PVC play-balls and a small boat.

Detailed description of the process related to caprolactam, powder polymers and sandwhich structures embodying solid outer layers enclosing foamed cores are included.

Because of the favourable balance of investment and production costs numbers in the range of 5,000 to 10,000 parts per year are economic.

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