Res. Prmme. No. 7/Res. Proj. No. 7/5/Rep. No. 1

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

CENTRIFUGALLY CAST IRON LINERS FOR I.C. ENGINE

BY
ROBERT MULLIN

ASRCT, BANGKOK 1976
not for publication

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

RESEARCH PROGRAMME NO. 7

MANUFACTURE OF FERROUS AND NON-FERROUS CASTINGS

RESEARCH PROJECT NO. 7/5

MANUFACTURE OF ENGINEERING IRON CASTINGS

REPORT NO. 1

CENTRIFUGALLY CAST IRON LINERS FOR I.C. ENGINE

BY

ROBERT MULLIN

ASRCT, BANGKOK 1976

CENTRIFUGALLY CAST IRON LINERS FOR I.C. ENGINE

By Robert Mullin*

SUMMARY

The process to centrifugally cast machinable grey iron has been developed to promote import substitution of some engineering castings. Initial attempts have successfully cast automotive cylinder liner blanks with fine-grained grey cast iron. Utilizing a single horizontal-type centrifugal machine and permanent mould, liners may be manufactured up to thirty units per hour depending on the size and wall thickness of the casting and providing that adequate melting facilities are available. The centrifugal casting machine used for this project is of simple design and can be easily constructed with materials available locally. The machine is adjustable and can handle a mould with the length of 35-65 centimetres and the outside diameter of 12-30 centimetres. With the range of sizes, cylinder liners or other automotive components such as bushings, piston rings, or gear blanks of various dimensions can be readily cast.

To obtain the proper microstructure and mechanical properties for automotive cylinder liners, so as to produce a grey, machinable cast iron, many factors must be controlled during the centrifugal process. Such factors include control of mould rotation speed, mould temperature, metal temperature, and mould coating composition and thickness. Each factor is discussed in this report including a typical grade of grey iron recommended for use as cylinder liners.

INTRODUCTION

A considerable amount of foreign exchange is lost annually due to the import of engineering castings. With the development of suitable foundry techniques, the local casting industry should be in a position to produce a variety of iron castings with quality comparable to those being imported. This project has been designed to introduce the centrifugal casting process, currently adopted overseas, and to demonstrate that suitable castings can be produced utilizing local materials and manpower. It is important to note that centrifugal casting is an all-embracing term and refers to any casting that has been rotated during

---

*Metallurgy Unit, Technological Research Institute, ASRCT.

the solidification period. This report concerns only with the horizontal-type centrifugal casting process in which the axis of rotation is horizontal and only a permanent mould is used. This process is widely used for the manufacture of cylinder liners, cast iron pipe, and other tubular-shaped castings. The resultant casting is of high quality, almost equal to that of forgings, and considerably better than static sand castings.

MATERIALS AND METHODS

The machine for horizontal centrifugal casting of cylinder liners is of simple construction (Figure 1) and is designed to accommodate permanent steel or cast iron moulds of various dimensions. A steel guard provides safety for the operator and is adjustable to accommodate the different length of moulds. A set of four nozzles are used to apply a high velocity jet of water against the mould for cooling. This fast heat removal, after casting, allows higher production rates. Moulds may be maintained at any desired average temperature by varying the length of time the cooling water is applied to the rotating mould. The pouring spout to direct the molten charge into the mould is mounted on the hinged door of the guard and is adjustable so the spout may be positioned on the centerline of the mould. The hinged door and pouring spout can be conveniently swung away to provide an access to the mould for the removal of the casting. Rotation of the mould on four trunnion wheels is provided by a 5 horsepower electric motor and a V-belt drive.

In order to obtain the proper microstructure and mechanical properties for cylinder liners so as to produce a fine-grain and machinable grey iron, it was necessary in this project to carefully control many factors during the casting procedure. These are discussed in detail as follows:

1) Permanent mould

The seamless steel permanent mould, made from AISI Grade 1020 steel, was preheated to a temperature of 315°C (600°F). This was done with a gas torch while the mould was rotating. Temperature of the mould was easily determined by the use of temperature marking crayons. Although no local supplier is found for these crayons, they can be readily obtained

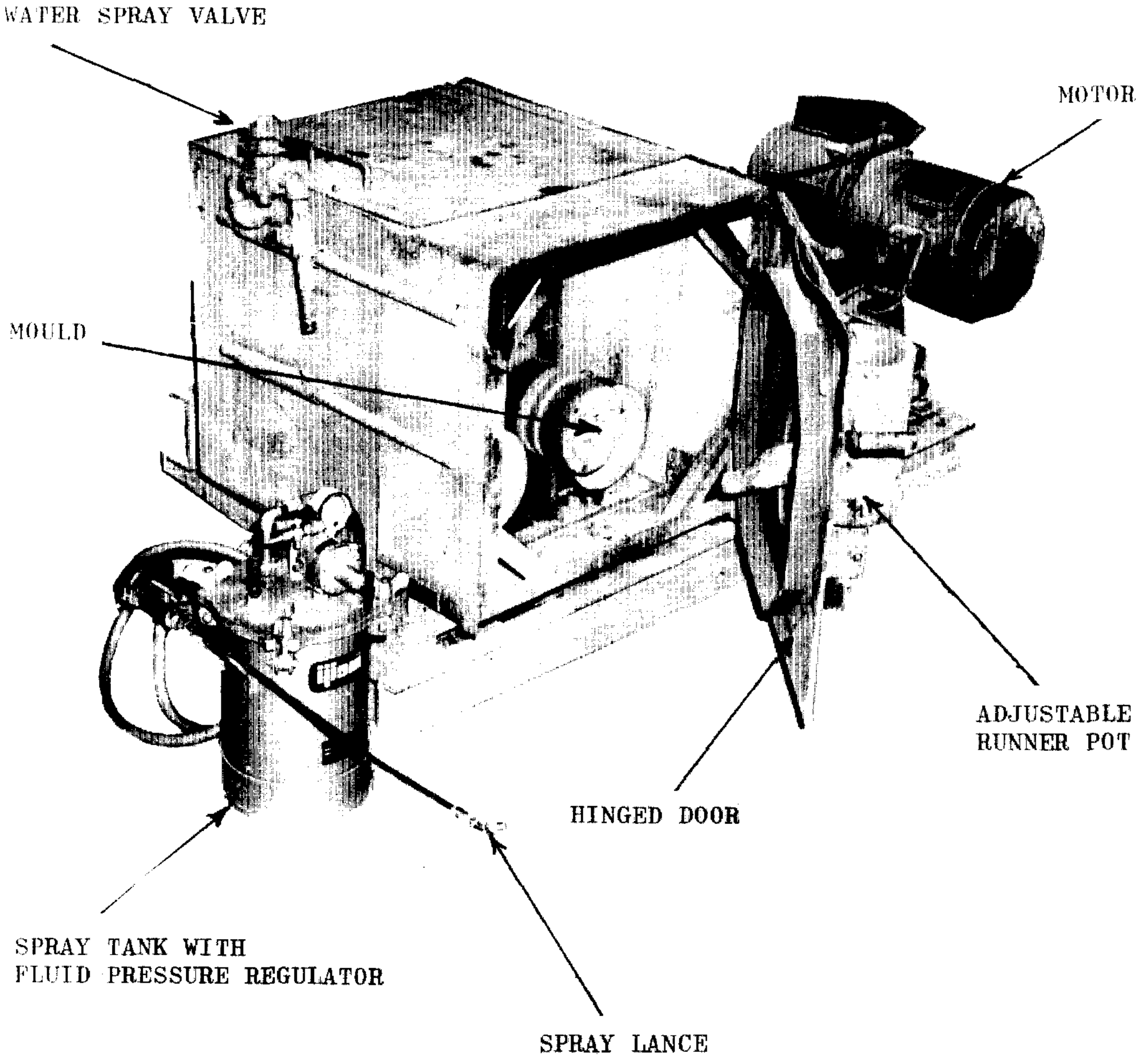

Figure 1. Horizontal centrifugal casting machine.

from overseas (Tempil Corporation or Markal Company in the U.S.). The usual life of these steel moulds will vary from 1,000 castings to 10,000 castings depending upon the service to which they are imposed.

The minimum amounts that should be added to each side of the finished casting as machining allowances are shown in Table 1.

TABLE 1. MACHINING ALLOWANCES

Casting size (diam.)	O.D.	I.D.
5-20 centimetres	2 millimetres	2 millimetres
20-30 centimetres	3 millimetres	3 millimetres

2) Mould wash

A suitable wash or coating was next sprayed into the mould with a coating thickness of approximately 2-3 millimetres. The recommended coating formula is shown in Table 2.

The bentonite and water were mixed in the proper proportions and allowed to stand for 24 hours. Then the silica flour was added and the mixture was allowed to stand for an additional 12 hours. This basic wash could be made up in advance so that it was always available when needed and it would keep indefinitely. When ready for use, sufficient water was added until a viscosity of 20 to 25 seconds was obtained on the No. 316 viscometer. Details of the viscometer are shown in Figure 2.

TABLE 2. MOULD WASH COMPOSTION

Ingredients	By weight	Example
Silica flour (200 mesh)	96½%	11.3 kg
Western Bentonite (High-gelling type)	3½%	0.4 kg
Water	-	5.7 litres

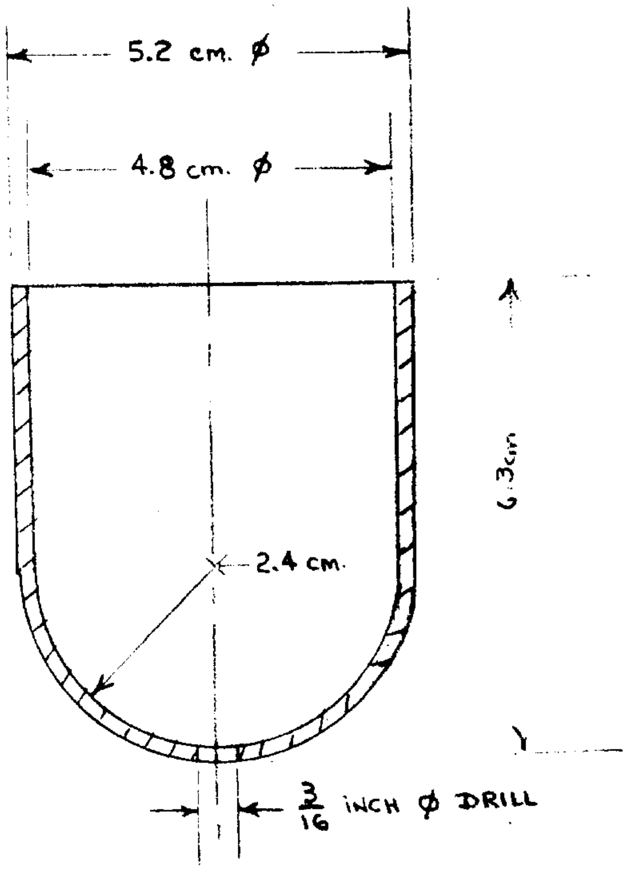

Figure 2. No. 316 Viscometer.

Since the mould wash is very critical for the centrifugal casting, any deviation from this formula is not recommended. It is the function of the mould wash when used on a permanent mould to serve as an insulating refractory material. The use of the mould wash, when applied in sufficient thickness, insulates the mould and hence reduces the surface temperature, and as a result increases the life of the permanent mould. The mould wash is also refractory enough so as not to be affected or reacted with the molten metal. The insulating characteristic is necessary in the wash to slow the initial rate of solidification of the molten metal to eliminate the formation of cold shuts, laps, and other defects.

Equally important is a satisfactory spray apparatus to coat the inside diameter of the mould. A pressure feed paint tank is recommended (as shown in Figure 1) so that the fluid pressure may be easily adjusted to produce a uniform spray pattern. The pressure tank was connected to a long spray lance with a nozzle angled at 45 degrees. The spray tip is readily obtained locally and is the same type used in agriculture to spray insecticides. The nozzle and lance assembly is fitted with a quick opening valve. Best results were obtained when the mould coating was sprayed while the mould was rotating at the same speed that was used for pouring the molten metal. The mould must be at the preheated temperature of approximately 300°C to get good adhesion of the coating. If the temperature is too low, the wash may not thoroughly dry and may cause pinhole defects in the casting. Also, the coating will not adhere as well to the mould and may be eroded away by the entering molten metal.

3) Mould speed

The acceleration obtained in the centrifugal casting depends on the diameter of the casting and the speed of rotation of the mould and can easily be determined from the nomograph shown in Figure 3.

To find the acceleration, in multiples of the gravitational unit, for a given casting at a given speed of rotation, draw a line from point on the leftmost scale (indicating the inside diameter of the casting) through point on the diagonal scale (indicating the speed of rotation) to the acceleration scale at the right.

For casting grey iron, rotation should be at a speed within the range that produces acceleration of 60 to 120 gravitational units. Broken lines show the use of the nomograph for determining maximum and minimum speeds of rotation that define this acceleration range for a 6 inch I.D. casting.

4) Metal temperature

The metal is generally poured into the rotating mould at a somewhat higher temperature (about 40°C higher) than that used for the same casting if poured statically. For grey iron the temperature should be at least 1,350°C.

Pouring rates required for the successful centrifugal casting should be high to prevent laps or laminated castings. For most types of castings which weigh 50 kilogrammes or less, a pouring rate of approximately 5 kilogrammes per second is recommended.

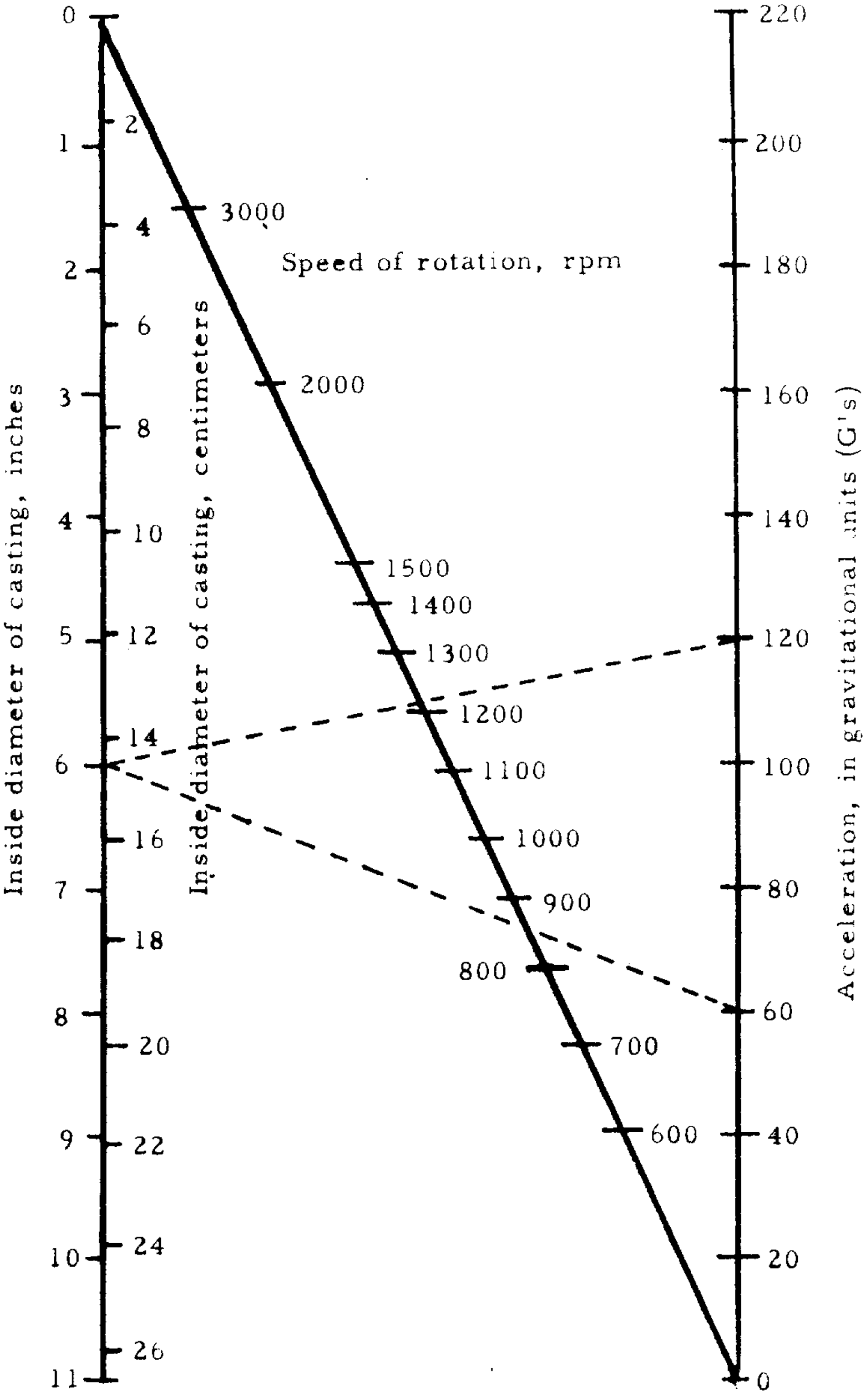

Figure 3. Nomograph for determining speed of rotation for grey iron only.

5) Water cooling

Each casting pour will increase the mould temperature. To maintain the desired mould temperature of 315°C, the water cooling nozzles should be opened immediately after pouring the molten metal. The valve should be left open as required to remove the proper amounts of heat from the mould. After a short time, the machine operator can easily estimate the length of time for water spraying. After a sufficient cooling, the casting can be extracted from the mould. The mould is still at the required temperature and is ready for recoating and casting again.

RESULTS AND DISCUSSIONS

Grey iron cylinder liners of exceptionally high quality were shown to be readily cast by the centrifugal process. The rapid unidirectional solidification from the outside surface assured a fine-grain, uniform, well-fed structure. The centrifugal force removed all gas holes and assisted in forcing lighter constituents such as non-metallic inclusions toward the center, where they could be easily machined away. The rapid solidification also permitted little segregation of the cast iron.

A review of current metallurgical literature indicated that most automotive cylinder liners in the United States are made from American Society for Testing Materials (ASTM) Class 30 grey cast iron with a minimum tensile strength of 22 kg/mm^2 (30,000 psi). This material was selected for the project, and the resultant centrifugal castings, designated Samples 1 and 2, were found to have the chemical composition shown in Table 3.

TABLE 3. CHEMICAL COMPOSITION

	Recommended ASTM Class 30	Samples 1 and 2 cast at ASRCT
Total carbon (%)	3.20/3.40	3.30
Silicon (%)	2.10/2.30	2.35
Phosphorous (%)	0.15/0.30	0.07
Sulphur (%)	0.08/0.12	0.07
Manganese (%)	0.50/0.80	0.31

The recommended chemical composition is for a casting with metal section size 1.5 to 2.5 centimetres. A larger wall thickness of the casting would require a lower carbon and silicon content to maintain the proper structure and mechanical properties. The desired hardness range for this grey iron composition is Brinell Hardness Number 179/230. For this material, the desired microstructure that would offer the required wear resistance and strength should consist of fine ASTM Type A graphite flakes (uniform distribution, random orientation) in a pearlite matrix. This structure was obtained in both centrifugal castings, Samples 1 and 2, as shown in Figure 4.

MAGNIFICATION : 250 x
ETCHANT : 2% NITAL

Figure 4. Microstructure.

Table 4 lists the various casting variables that were controlled during the centrifugal process and the resultant mechanical properties obtained for both samples.

The production of Type A graphite in a permanent mould was readily obtained, through the entire metal section, by maintaining a mould temperature of 300°C and by coating the inside diameter of the mould with a minimum of 2 millimetres mould wash. This procedure was followed for Sample 1. A lower mould temperature, as attempted in Sample 2,

TABLE 4. CASTING VARIABLES AND MECHANICAL PROPERTIES

	Sample 1	Sample 2
Metal temperature (^{o}C)	1,350	1,350
Mould temperature (^{o}C)	315	150
Coating thickness (mm)	2	2
Centrifugal force	90 G's	90 G's
Hardness (at 1/2 radius)	BHN 228	BHN 228
Tensile strength[1/] (kg/mm^2)	27	29

[1/] Approximate value, estimated from hardness.

was found to produce a casting with an extremely hard surface. Examination of the microstructure of Sample 2 had shown a "mottled iron structure" near the casting surface, which is a mixture of white iron and grey iron areas. This undesirable condition occurred because of low mould-temperature (only 150^{o}C) which caused the molten iron to solidify very rapidly, suppressing the formation of graphite and producing areas of extremely hard white iron near the surface. The white iron structure should be avoided because it is difficult to machine.

It should be noted that other compositions, strengths, and microstructures of grey iron would be suitable for cylinder liners. The final detailed choice of composition is based on the requirements that govern the design of the liner being considered. For example, a liner used in diesel engines would be subject to more severe conditions than the one used in an automotive gasoline engine.

A special aspect of this report is that the centrifugal process as outlined can be further expanded to manufacture several other automotive components with only minor changes in the technique. This includes both ferrous and non-ferrous castings such as piston ring blanks, bushings, and gear blanks. Although such components may be produced by the less expensive static sand casting technique, the centrifugal process would produce a much higher quality casting, almost equal to that of a forging. In addition, the centrifugal process has the advantage of higher production rates and nearly a 100% casting yield i.e., no metal is required for gates or risers as in sand castings. The only disadvantage is that the facilities for centrifugal casting are somewhat more expensive than sand castings, although the smaller floor space area requirements of centrifugal casting may offset the greater expense.

ACKNOWLEDGEMENTS

The author wishes to thank the Royal Irrigation Department for loan of the centrifugal casting machine.

REFERENCES

AMERICAN SOCIETY FOR METALS (1970).—"ASM Metals Handbooks." 8th ed. (American Society for Metals: Metals Park, Ohio.)

BERRY, J.T. (1961).—Foundry. 89: 96.

CENTRIFUGAL CASTING MACHINE COMPANY. (1975).—Centrifugal casting manual. (Tulsa, Oklahoma.)

WALLACE, J.F. (1953).—Trans.Am.Fndrym. 61: 701.