Developing a Bearing Spin-Casting Facility

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Abstract

Verve Energy currently uses the pour casting technique to refurbish their steam and gas turbine whitemetal bearings. However the alternative of using spin-casting, which is currently not available in Western Australia, offers a number of potential benefits. The objective of the project therefore is to identify these benefits and provide technical details of the machinery, equipment and materials required to develop a spin-casting facility, together with estimates of the total expected capital and operating costs. Current estimates value the facility at $1.89 million dollars with an investment of $568,200 in equipment. The ultimate aim is to determine whether a spin-casting facility is a viable proposition in Western Australia, and if it is not, to identify the conditions in which it will become viable. The project will advance the current state of the art by providing the first design proposal for a purpose built bearing spin-casting facility in Australia.

1. Introduction

Verve Energy is Western Australia's leading energy provider, with a total generating capacity of just below 3000MW. The entity owns and operates several major power stations that are installed with a series of gas and steam turbines. Reliable operation of the turbines is critical to Verve's business and as such it is essential that the turbines are maintained and that major components including the turbine rotor bearings are routinely repaired.

The rotor bearings are made from steel and are internally lined with a tin-based whitemetal alloy several millimetres thick. The whitemetal is used for its excellent anti-friction properties and embeddability and conformability characteristics which in short lead to reduced friction and wear between the shaft and bearing. During operation however the whitemetal lining wears, and may suffer consequential damage from mechanisms such as high vibration, and consequently needs to be replaced. When this is the case the bearings are removed from the turbines and sent to an external workshop for remetalling where the worn whitemetal lining is removed and a new lining is re-cast using a manual pour-casting technique. This method of relining is commonly practiced and provided the fabricator is well experienced, can produce a high quality lined bearing with a sound bond.

Spin casting however provides an alternative technique of whitemetal bearing refurbishment, with quality less dependent on operator skill. The purpose of this research was to investigate the technical and commercial issues involved in setting up a spin-casting facility in Western Australia and to highlight the alternative business strategies available for developing such a facility.

1.1 Background of Whitemetal Bearing Repair

Whitemetal bearings are produced using either manual pour casting or by spin-casting with a centrifugal casting machine. The objective is to produce a sound lining which adheres firmly to the bearing shell through good chemical bonding and this can be achieved using either method with relative advantages and disadvantages.

1.1.1 Pour Casting

Pour casting involves tinning the bearing shell and manually pouring fresh molten whitemetal with a ladle into a jig setup similar to that shown in Figure 1. Tinning is the most critical stage of the lining process and is required to achieve an effective bond between the lining and the shell (ed. Adams 1973). The steel shell is first coated with a thin layer of pure tin which forms strong positive bonds with both the shell and the whitemetal holding them securely together (Babbitt Bearing Alloys 2009).

It is critical to pour the whitemetal at the correct temperature and to ensure directional solidification of the whitemetal from the outside toward the bore to avoid formation of any shrinkage porosity in the lining (ed. Adams 1973; Babbitt Bearing Alloys 2009). Cooling inward ensures any porosity is contained within the machine tolerance at the bore and can later be removed. A riser is added to the top of the shell to allow additional molten metal to be poured which feeds the solidifying metal below. This is later machined off.

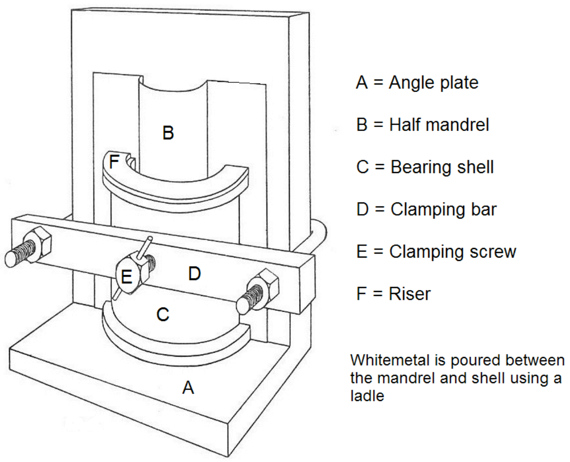

Figure 1 Jig setup for pouring a half bearing

It is critical that the fabricator "puddles" the lining as it cools using a stainless steel rod. Puddling is done to remove air bubbles and requires experience. Care must be taken not to pierce the semi-solid lining as it forms at the bottom and to avoid splashing of the metal and entrapment of air in the final lining (ed. Adams 1973).

1.1.2 Centrifugal Casting

Centrifugal casting is an advanced form of casting that uses a rotating machine to cast the lining onto the bearing shell. Unlike pour casting this method has a reduced dependence on fabricator skill.

A dual-faceplate, horizontal axis machine is used for the purpose of lining whitemetal bearings as is shown in Figure 2 (CCMCO 2006; Gibson Centri-Tech 2009). The tinned bearing shell is mounted between the faceplates which are clamped tightly together and hold the bearing centred about the horizontal spinning axis. A protective cover is then pulled over the spinning assembly and water jets are fired onto the bearing shell to enhance directional cooling towards the bore. During operation the faceplates rotate and molten metal is poured in through a pouring funnel that protrudes into the bearing shell as shown.

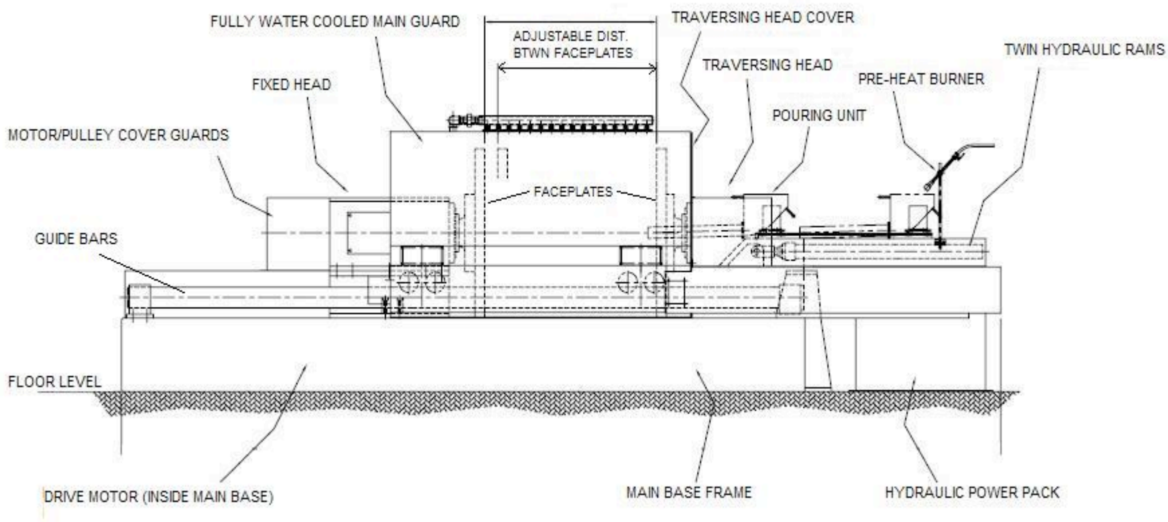

Figure 2 Dual face-plate centrifugal casting machine / Babbitt lining machine

Since no mold core is used, the spinning speed must provide sufficient centrifugal force to distribute the molten metal along the length of the bearing shell and hold it firmly against the shell wall without dripping or "raining" as this will seriously detriment the integrity of the bond. The speed must not be too high however as excessive tensile stress in the outer diameter of the casting may result in the formation of longitudinal cracks or hot tears (Cumberland 1963; Janco 1988).

1.2 Project Objectives

The primary objective of the project was to investigate the alternative method of spin-casting and identify any potential benefits it may offer over the current method of manual pouring. Given that there is no existing spin-casting facility in Western Australia the project aims to provide technical details of the machinery, equipment and materials required to develop a new spin-casting facility, the expected capital outlay and operating costs of such a facility and ultimately to determine whether it represents a viable business venture. The project will advance the current state of the art by providing the first design proposal of a purpose built bearing spin-casting facility in Australia.

2. Investigation Plan

In order to achieve the project objectives a good understanding of each remetalling technique and the practices used by existing manufacturers was required. To achieve this literature on both centrifugal and pour casting was reviewed, as well as background information regarding the design of bearings and properties of whitemetals. Site visits to local whitemetal casting facilities were also arranged to gain an understanding of the practical requirements of manufacture.

Following this an equipment list was developed that detailed all of the equipment required to spin-cast bearings of the size used by Verve Energy. The casting machine model was selected to have adequate capacity to fabricate all bearings in the size range. It was assumed that all equipment would be purchased new and consideration was given to shipping, freight, import taxes, installation and commissioning charges. For large equipment items a number of vendors were contacted for price comparison.

An approximate workshop size and land plot was then determined based on the equipment footprints with an added allowance for adequate storage areas, walkways, vehicle access and office space. Expected construction costs were then quoted by a local construction company for a standard 10m high steel cladded workshop with a 150mm reinforced concrete slab, overhead crane, offices and bitumen hardstand covering the yard.

Operating costs per annum, including maintenance, consumables, electrical power and labour, were then estimated and used to calculate the fixed cost per bearing produced. This figure will then be used to determine the required throughput of bearings needed to make the project viable.

Alternative strategies to Greenfield construction are now being investigated in order to give the client several options of commercially structuring the project. The cost of alternatively leasing a vacant workshop or expanding an existing pour-casting facility will be compared to the cost of Greenfield construction. Again the required throughput that makes each option viable will be highlighted. This information can then be used by the client to determine the most favourable approach and will provide the basis of future more in depth studies.

3. Results and Discussion

3.1 Benefits of Spin-Casting

The results of the investigation into remetalling techniques show that spin-casting does offer a number of benefits over pour-casting including:

- Elimination of shrinkage porosity. The centrifugal force ensures each successive increment of the metal to solidify is pressure fed by the residual liquid metal in contact with it until solidification is complete (Cumberland 1963; Janco 1988).
- A very clean metallic structure free from impurities. Slags and non-metallic impurities float toward the bore during spinning and can later be machined off (Irving 1975; Royer 1988).
- A very dense, equiaxed grain structure with uniform properties in both the traverse and longitudinal directions (Cumberland 1963; Irving 1975; Royer 1988). Consequently the mechanical and fatigue properties are better than those achieved using static casting which tends to produce a coarse grain structure (Chirita, Soares & Silva 2008; Gromyko 1990; Irving 1975; Royer 1988).
- Reduced dependence on operator skill and experience. Perfect directional solidification can be achieved with little or no effort on behalf of the operator. The casting machines are simple in design and require minimal training.
- The process also lends itself readily to automated production and fast turn-around in terms of delivery (Irving 1975).

Attaining these benefits however will require investment in specialty equipment and will result in higher maintenance and operating costs than pour casting. There is also some risk associated with a lack of experience of appropriate spinning speeds and a consequent learning curve is expected.

3.2 Required Equipment & Materials

The centrifugal casting machine is the principal item of equipment required. The two leading suppliers of this technology are The Centrifugal Casting Machine Company Inc. based in the USA and Gibson Centri-Tech based in the United Kingdom. Both companies can supply models with suitable capacity to Australia.

Following this, the only other significant equipment required is for machining. A lathe is required for boring and facing operations and a mill for cutting oil grooves and surface details. Given the large size of the turbine bearings a heavy duty lathe with at least 1000mm swing is required. Similarly a large turret milling machine is needed. A Clausing MA Series 40" lathe and Manford 5KV mill are recommended for the application.

Stocks of whitemetal alloys, tin ingot, lead ingot and tinning compound are also required for casting. Ecka-granules supply the required HOYT 11R whitemetal while Consolidated Alloys in Australia stock a similar tin based whitemetal known as DIESEL.

3.3 Workshop Size

A workshop of area of approximately 550 square metres plus 70 square metres of office space will accommodate the required equipment and allow sufficient space for storage and operations. Based on this a site of approximately 1750 square metres is required to develop the facility.

3.4 Expected Costs

The total capital cost of developing a new Greenfield spin-casting facility is detailed in Table 1. The equipment price includes shipping, import tax, freight, installation and commissioning charges.

Item	Cost
Equipment	$568,200
Land	$437,500
Construction	$883,500
TOTAL	$1,890,000

Table 1 Estimated capital cost of developing a new spin-casting facility

Machining equipment accounted for 46% of the total equipment costs with casting equipment only accounting for 35%. There is thus a considerable saving to be made by utilising an existing machining shop. Interestingly there was a considerable difference in the prices quoted for the centrifugal casting machine. The machine from the USA was significantly cheaper than the machine from the UK with the final converted price including delivery 57% cheaper. This difference could not be justified by differences in exchange rates and there were no significant technical differences between the machines. There was no evidence of any superior control systems or operating efficiencies.

4. Conclusions and Future Work

The project findings to date indicate that a purpose built whitemetal casting machine of suitable size and capacity for Verve Energy's application can be purchased and imported to Australia. Secondly, the machine from the USA is preferred due to price. Thirdly, due to the high costs of construction it is concluded that either leasing or Brownfield expansion is preferable due to the significant decrease in capital investment. Only investment in equipment will be required and this investment may be considerably less than the quoted $568,200 if second-hand equipment were to be purchased. Sourcing second-hand equipment prices is recommended for future work.

Given the relative simplicity of the dual face-plate centrifugal casting machine, it is proposed that a machine could be designed and fabricated here in Australia at a significantly reduced cost to those quoted from CCMCO and Gibson Centri-Tech. As a part of this project the alternative of constructing a dual-faceplate machine locally will be proposed. This will include initial design work and drawings of a test rig that may be constructed and tested as a part of a future project.

5. Acknowledgements

I would like to thank my supervisors Mark Smart and Nathan Scott for their ongoing support through out the project. In addition I would also like to thank Alex Bologa (AB Engineering) who has contributed a significant amount of expertise in the area of bearing remetalling. His willingness help and contribute toward the project has been very much appreciated and deserves due recognition.

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