On Servitization and Maintenance of Diamond Press Machines

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Abstract

A typical diamond press is designed to operate under high pressure and high temperature in order to simulate conditions that are similar to that within which nature produces diamonds. The manufacturing of synthetic diamond demands very special attention to the operation and maintenance of machinery. Product servitization is increasingly transforming the business models for designers, manufacturers and vendors of engineering assets, and suppliers of diamond press machines are not immune to this trend. This paper takes the practitioner view that servitization is also a major issue for custodians, owners and operators of diamond press machines, and argues that this could be one of the reasons why increases in maintenance expenditure may not result in increased availability of machines deployed by the synthetic diamonds manufacturing company used as case study.

Keywords
Servitization-Driven Outsourcing · Total Productive Maintenance · Diamond Press Availability

1. Introduction

Diamond press machines are used to manufacture synthetic materials for applications in a diverse range of industry sectors. The typical cubic press machine comprises electromechanical and hydraulic components, equipment, and systems that are integrated to simulate conditions in which diamonds are formed.

The maintainability of a diamond press depends on the design of the machinery but the availability depends on how the machine is operated and maintained. Operators and maintainers (referred to as 'users') need to appreciate the design limitations of the diamond presses in as much as designers, original equipment manufacturers (OEMs), suppliers and vendors (grouped as the 'logistics support chain') need to understand the vagarious business requirements for the machines, as well as provide necessary support to the corresponding diverse operating environments that the machines will be subjected to.

Although designers and OEMs may naturally focus on the technological aspects of creating the machine, and the vendors traditionally focus on marketing and selling the technological capabilities embedded in the machine, however, the synthetic diamond manufacturer conventionally considers the machine as an asset, as a means to achieve business objectives usually centred around high throughput at the minimum cumulative cost of ownership. It is in this regard that operators and maintainers focus on the service delivery capability of the machine.

The acquisition of a diamond press often presents challenges to supplier/client relationship, and affects the transfer of knowledge between the components and equipment designers, systems integrators, the machine operators and the equipment maintainers. Such misalignment and knowledge gaps often arise due to ill-defined agreements that do not sufficiently articulate servitization issues like technology and technical support arrangements that will be required well beyond the acquisition phase of the machine. In such cases, it is not uncommon that unclear requirements for ongoing technical support for the operation and maintenance of the machinery exacerbate the conflict between concurrent minimization of costs and maximization of throughput.

2. Servitization and Total Productive Maintenance Considerations

2.1 Servitization

Original equipment manufacturers, vendors, integrators and suppliers of spares recognise the emergent strategic importance of bundling services together with components, equipment, and systems that constitute a diamond press

machine (see, for example, Smith et al. (2011)). Although there are differences between products and services, however, Johnson and Mena (2008) contend that "servitized supply chain requires careful synchronization of product and service … in order to deliver a complete product-service proposition to the customer." In a multi-firm scenario, the servitization supply chain may involve a complex network of providers of products and services. From a business operations viewpoint, on the one hand, servitization in terms of bundled technology and technical support presents complex service challenges (Howard and Caldwell 2010). On the other hand, servitization also presents new opportunities for improving the operations and maintenance of the machines deployed for manufacturing synthetic diamonds.

As OEMs, suppliers and vendors of diamond presses confront paradigmatic re-alignment of their business models to servitization imperatives (Barnet et al. 2013), this also provides impetus for the users of these machines to re-engineer and restructure their operations and maintenance organizations policies, tactics and practices. For a synthetic diamond manufacturer, this not only requires investment in co-creative skills for operations and maintenance personnel but also, it necessitates changes and transformation in organizational culture and norms (Weeks and Du Plessis 2011) in order to exploit the servitization paradigm.

With the focus on manufacturing synthetic diamonds, it is not uncommon for the maintenance of the machines to be contracted out to OEMs in particular. As discussed in Colen and Lambrecht (2010) and Colen et al. (2012), the servitization-driven outsourcing of maintenance demands cross-training of personnel especially within the service provider organization with broad re-classification of maintenance policy in terms of "emergency" and "non-emergency" work. Cross-training is also necessary for the client organizations, in as much as servitization-driven outsourcing imposes a re-think on total productive maintenance concepts and practices.

2.2 Total Productive Maintenance

From the viewpoint of a synthetic diamond manufacturer, a penultimate goal is to maximize the throughput and yield through each machine deployed. The components, equipment, and systems that constitute a diamond press may be acquired from many suppliers such that the servitization strategy of the machine custodian/owner may require the coordination of a complex network of product and service providers. It is in this regard that Johnson and Mena (2008) reiterate that information flow that links real-time condition data to the supply chain can improve responsiveness to maintenance and spare parts provisioning. Prescribing total productive maintenance strategy and the implementation thereof (Pophalay and Vyas, 2010; Ichniowski and Shaw, 1999), in the context of servitization-driven outsourcing of maintenance, should at least, be geared towards high availability and utilization of diamond press machines over the longest useful life possible (i.e., $\boldsymbol{t}_{acq} < t < \boldsymbol{t}_{eoul}$). As illustrated in Figure 1, expenditure to operate and maintain the machines contribute significantly to the total cost of ownership, thus for any owner/operator, it is always an imperative to be in control of the costs of operating and maintaining a diamond press machine.

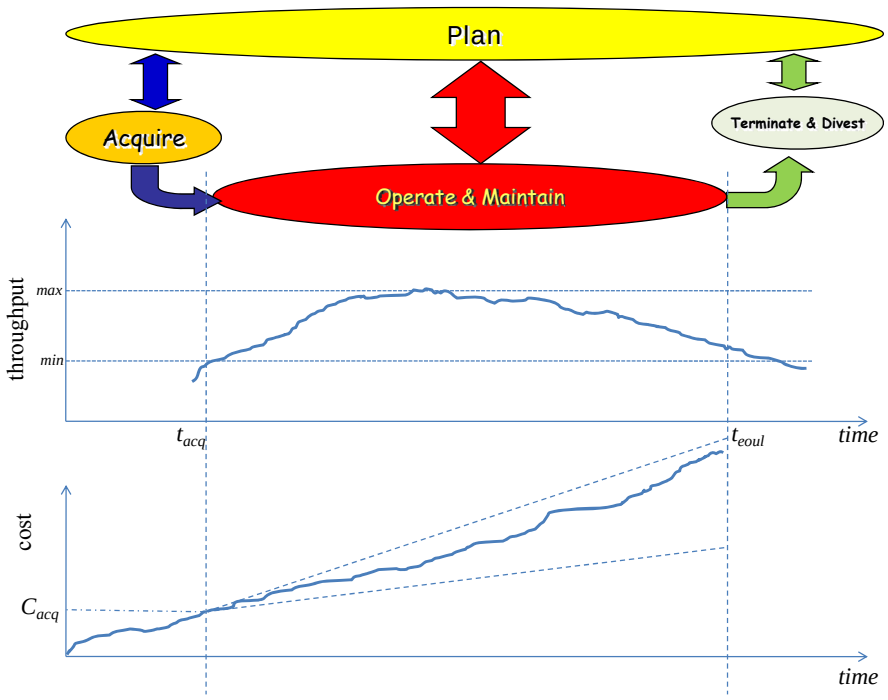

Figure 1: User/operator view of throughput and life-cycle costs of a machine

Although conventional practice often tends towards brutal attempts to reduce operating and maintenance costs in the short term, however, it is rather reasonable to skillfully manage the rate at which such costs rise over the longer term. The proposition here is that servitization-driven outsourcing should be targeted to reduce misalignment and knowledge gaps, as well as to improve the transfer of knowledge between the components and equipment designers, systems integrators, the machine operators and the equipment maintainers. The link between product-servitization and innovation (Dachs et al 2012) presents even a greater challenge of technological obsolescence and organizational reform to the machine custodian/owner and operator. For the machine custodian/owner and from the total productive maintenance perspective, the link to the supply chain that involves a complex network of providers of the required components, equipment, and systems may not be trivial. The question arises as to how implement total productive maintenance principles to align with the emergence of servitization-driven outsourcing. The rest of the paper briefly describes the initial stages of an ongoing study that is intended to examine this question.

3. Case Study

Our inexhaustive literature review suggests that servitization-driven outsourcing tends to be studied from the service provider perspective (see, for example, Turunen, 2012; Steunebrink, 2012; Dachs et al, 2012). Our approach is to study servitization-driven outsourcing from the perspective of the custodian/owner of the machine and recipient of the service. We have also adopted a single case study method at this exploratory stage, to enable us to gain better understanding of the unclear issues surrounding servitization from a custodian/owner perspective, and subsequently to articulate our research in detail. The company referred to in our case study operates more than 50 diamond press machines. It is in this regard that we

- examined documented records to identify the rate of, and possible causes of machine failures,
- conducted interviews with personnel to gain appreciation of the prevalent human perceptions,
- made direct observations in order elucidate latent factors.

Data arising from the synthetic diamond producer in our case study indicated that the increasing cost of maintenance did not result in increased availability of the presses deployed. As illustrated in Figure 2, normalised maintenance expenditure was generally above budget and increased from 2.3 units, 2.5 units, 3 units, and jumped to 4.3 units between 2008 and 2011 respectively. The availability the diamond press machines corresponding fluctuated between 67%, 61%, 72% and 66% during the same financial periods. Although Murty and Naikan (1995) have demonstrated

that increasing maintenance expenditure beyond the optimum availability may be futile, however, it is conventional to expect that increased maintenance expenditure should, at least, result in sustained availability of the machines.

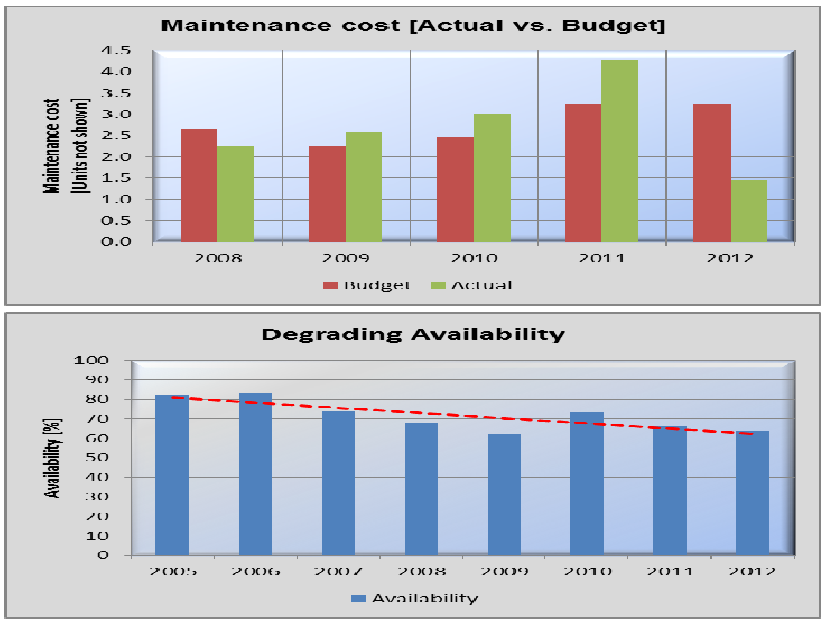

Figure 2: Trends in maintenance costs and availability for the case study company.

Each diamond press machine deployed in our case study company typical comprises anvils, hydraulic pistons, pipes, valves, electronic and electromechanical components. From the company's production records (see Figure 3), our examination of 1876 instances of failures between 2006 and 2011 showed that more than 38% were attributable to electrical faults, 17% to oil leaks, 11% to blowouts, 10% to misalignment of the anvils, and over 8% were attributable to 'human error'. It is not surprising that most of the failures recorded were due to electrical faults. Diamond synthesis within a press occurs in a capsule enclosing electrical resistance heating element encapsulated within the anvils, and the heat from the resistance element is likely to damage the insulation that protects the anvil.

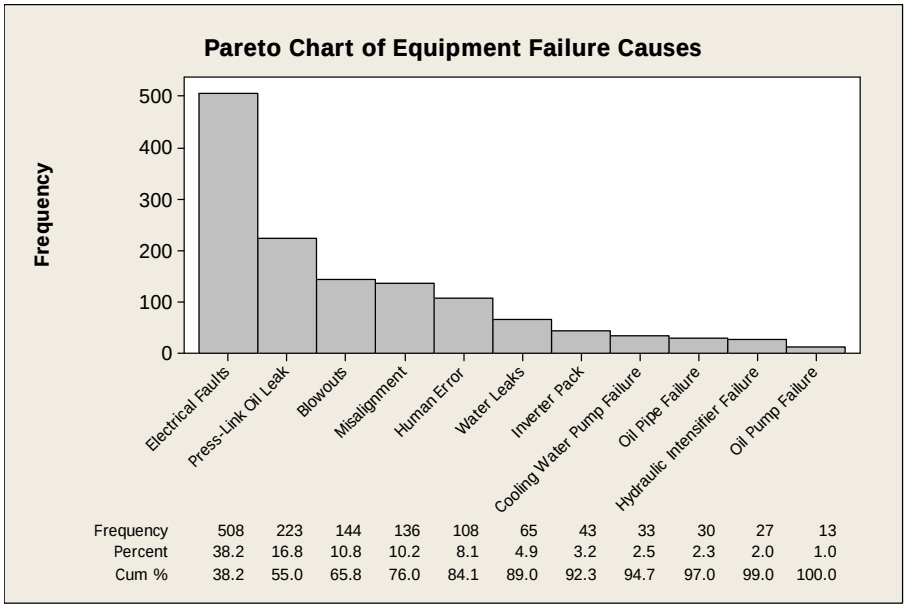

Figure 3: Recorded causes of machine failures.

The top graph in Figure 4 shows the split of the maintenance expenditure, indicating that personnel training contributed less than 5% of costs over the 35 periods under examination. The lower graph illustrates the disparity between planned versus actual duration of maintenance tasks. Further examination of maintenance records revealed that 'planned maintenance' was, in fact, in reaction to failure occurrence. The predominant maintenance repair activity was stripping and fixing leaking hydraulic cylinders and seals, and re-machining of scoured anvils.

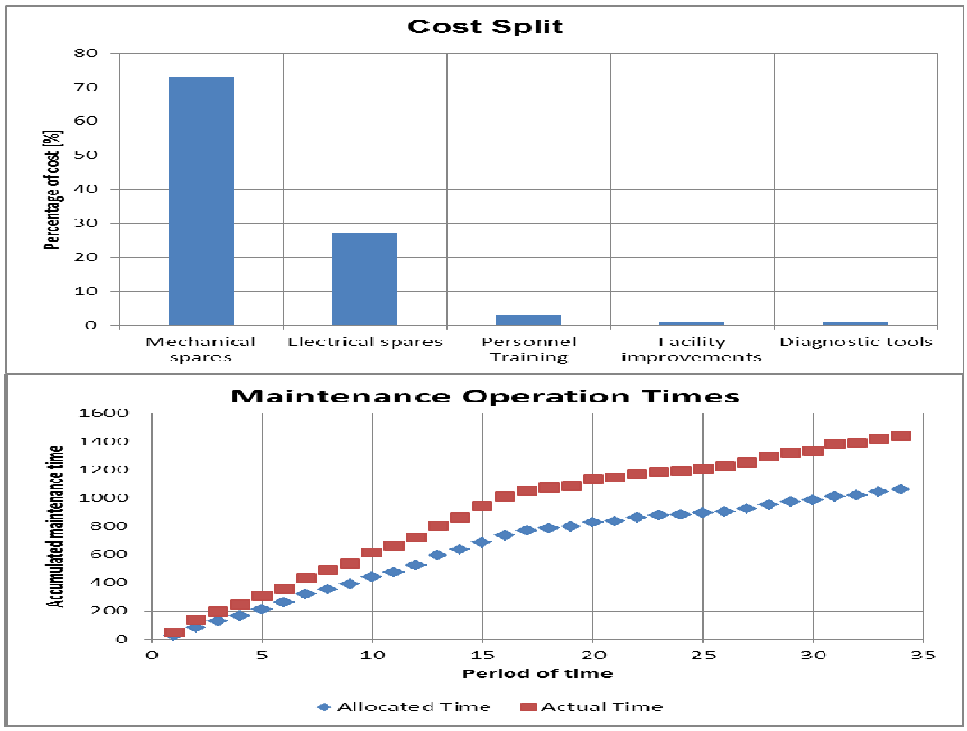

Figure 4: A view of maintenance performance for the case study company.

Direct observation showed that there was no specially designated maintenance workshop. Items of equipment that constitute a diamond press machine can be quite heavy, thus the layout of the production facility includes some overhead cranes to minimize the logistic cost of getting spares to the required machine location. With over 8% of the recorded failures attributable to human error, we conducted narrative interviewing of some personnel responsible for operations and maintenance. For brevity, the persistent inference from the narrative enquiry interviews is that the operations and maintenance organization appears better skilled at resolving failures rather than preventing them. Therefore, it was not surprising that increased maintenance expenditure did not translate into improved availability of the company's machines over the period that we examined recorded data.

4. Discussion and Conclusion

One preliminary finding is the strong suggestion that operational demand for high throughput induces electrical instabilities and consequent mechanical failures of the machines deployed by our case study synthetic diamond manufacturer. In as much as the direct observations indicate to us that technological obsolescence and other organizational challenges require research attention, however, it is remarkable that the interview responses support the viewpoint that the competence of the operators and maintainers is geared more towards fixing failures. The seemingly low expenditure on personnel training relative to mechanical spares highlights this remark. Our attempt to further understand the reasons for classifying over 8% of the recorded causes of failure as due to human error is an ongoing challenge as respondents seem unwilling to offer explanations. We suspect that this claim may be incorrect, considering the evident disparity between the purported 'planned' and the actual duration of maintenance tasks.

We understand that the machines were acquired well before 2006 and the purchase and installation records were not readily available to us. Also, we have not had access to any reliable information regarding the technical support agreements in place. Therefore we have not been able to examine such documentation in order to establish the level of servitization implied in the transactions between the case study company and the suppliers of synthetic diamond manufacturing machine components, equipment and systems. Thus, in addition to other intra organizational challenges within the case study company, we suspect that the significant discrepancy (observed in the recorded data shown in Figure 2) between budget and actual maintenance expenditure may also be related to the type of servitization implied in the machine purchase and installation agreements.

Although our research has not been completed, however, with evidence of incessant failures and relatively low availability of the more than 50 diamond press machines deployed, there may be the need for the company to reconsider how it acquires its synthetic diamond manufacturing capabilities. The preliminary evidence gives us reason to believe that the company should seek more robust servitization arrangements with OEMs, suppliers and vendors of components, equipment, and systems that constitute the diamond press machines. Based on our preliminary findings, the custodianship/ownership and servitization strategy should be, at least, to align maintenance expenditure to optimum availability and throughput that can be achieved. The goal should not only be to reduce total costs of ownership but also, to optimise the ratio of the acquisition cost of a machine to its cumulative cost during the useful life cycle (i.e., $\boldsymbol{t}_{acq} < t < \boldsymbol{t}_{eoul}$). Tactically, it is reasonable to suggest that the company should refocus its total productive maintenance resources towards predictive identification of the potential failure interval of the components, equipment, and systems that constitute the diamond press machines. From an engineering asset management viewpoint, the wider ramification is that technical support agreements must engender cognitive preferences and behavioural attributes of ownership and custodianship (Amadi-Echendu 2012) in both the synthetic diamond manufacturing company and its servitization partners.

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Biography

Joe Amadi-Echendu is a professional engineer and professor at the Graduate School of Technology Management, University of Pretoria. His teaching, research and consulting interests cover engineering and technology management issues. Prof Amadi-Echendu has published over 100 papers and articles in refereed conference proceedings and journals. His is currently Editor-in-Chief of Scopus-indexed Engineering Asset Management Review Series published by Springer.

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