Leagile manufacturing and air compressor production: Connectivity establishment through state of the art researches

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Abstract. This paper reports a research which was carried out to establish connectivity between leagile manufacturing and air compressor production by studying the state of the art researches. Leagile manufacturing paradigm is incorporated with lean and agile manufacturing principles. This research was conducted in three phases. In the first phase, the researches on leagile manufacturing were surveyed. During the second phase of the literature survey, the research papers reporting the literature reviews containing the air compressor-based researches were reviewed. During the third phase of conducting this literature survey, it was found that so far, no efforts for examining the implementation of leagile manufacturing paradigm in air compressor industry have been made by the researchers The paper is concluded by indicating the need of designing an implementation model and conducting case studies to establish connectivity between leagile manufacturing and air compressor production.

Keywords: Lean manufacturing, Agile manufacturing, Leagile manufacturing, Postponement, Decoupling point, Air compressor and Literature survey.

1 Introduction

When the competition was highly sensed during the middle part of the twentieth century, the manufacturing companies had to look for the paradigm that would reduce or eliminate wastes for decreasing the cost of production of products and their prices [1]. As a result, the lean manufacturing paradigm was implemented in companies. The objective of lean manufacturing paradigm is to produce right products with right quantity and quality at right time for supplying to the right customers [2]. Soon after the publication of Womack et.al. [3], many companies in the world implemented lean manufacturing [4, 5]. These companies have reported to have decreased the price of the products due to the reduction or elimination of wastes during the production of products. Besides many researchers began to study and explore the implementation of lean manufacturing paradigm in companies [6 , 7].While the

ICAMDMS 2024, February 23-24, Coimbatore, India

DOI 10.4108/eai.23-2-2024.2347032

adoption of lean manufacturing paradigm in organization was taking place in the world, modern manufacturing companies are required to be agile in producing the products [8, 9, 10]. The researchers have named the set of activities facilitating this capability as agile manufacturing [11].

In one direction, a section of researchers have been working on applying lean manufacturing paradigm in the production of conventional products. In another direction, researchers have been working on applying agile manufacturing paradigm to produce new and innovative products [12, 13, 14]. When the world has been witnessing such development in two directions, Naylor et. al. [15] brought out the concept called leagile manufacturing [13]. As the title suggests, leagile manufacturing refers to the paradigm which combines lean and agile manufacturing paradigms [16, 17, 18]. Leagile manufacturing paradigm facilitates companies to produce products by applying lean and agile manufacturing paradigms separately as well as by applying these two paradigms in hybrid form [19].

A few researchers began to examine the implementation of distinct leagile manufacturing paradigm on the specific products [20]. For example, Krishnamoorthy and Yauch [12] have reported the implementation of leagile manufacturing paradigm in a company manufacturing product which are supplied to electronics products manufacturing companies and nuclear power plants. Likewise, [21, 22] have reported research on applying leagile manufacturing paradigm in the production of pumps. The outcomes of such kind of researches will enable the practitioners to adopt leagile manufacturing paradigm for producing conventional, hybrid and innovative models of the products which will cater to the requirements of several kinds of customers and increase the profitability of the companies. Though this kind of research on applying leagile manufacturing paradigm on specific products was begun by a few researchers about two decades back, such kind of researches are required to be carried out on certain other products which are used by the customers residing at different parts of the world. One such kind of product is air compressor that finds wide application.

Air compressor can be used for several applications like inflating the rubber tubes and effecting the automation. Air compressor is used for carrying out several other applications too. Notwithstanding the requirements of customers, practitioners have been producing at least 50 different types of compressors. Some researchers studied the implementation of lean manufacturing in companies manufacturing compressors [23, 24]. No researcher has studied the implementation of agile manufacturing in companies in which air compressors are manufactured. Today, companies are required to produce traditional air compressors by employing lean manufacturing and innovative air compressors by employing agile manufacturing. In other words, in order to be competitive, modern companies manufacturing air compressors are required to implement both lean and agile manufacturing paradigms. This imperative can be met by implementing leagile manufacturing paradigm [12]. In other words, the need of the hour today is to compress theoretically the leagile manufacturing paradigm into air compressor manufacturing environment. This task has been accomplished in the research presented in this paper.

2 Research Methodology

The research being presented here was carried out by following the methodology shown in **Figure 1**. As shown in this figure, this literature survey was begun by searching research papers containing the theories and applications of leagile manufacturing in the production of

air compressor. These research papers were searched in science direct database and databases maintained by four publishers namely Emeraldinsight, Taylor & Francis, Springerlight and Inderscience. The keywords used while carrying out these searches were 'leagile manufacturing' and 'air compressor'. This search did not yield any relevant results indicating that no reseach on applying leagile manufacturing in air compressor manufacturing has so far been carried out. Hence, papers reporting researches on leagile manufacturing and air compressors were gathered separately from the above databases. Then these papers were reviewed in two phases. These two phases of literature review were carried out in parallel. While carrying out this literature review, the basic theory and 'state of the art' researches on leagile manufacturing and air compressor were studied. By referring to the information drawn by conducting these reviews, the research gap was identified. The primary research gap identified was the absence of researches on developing the theoretical and practiced concepts of implementing leagile manufacturing paradigm in air compressor industry. In order to fill this gap, the connectivity between leagile manufacturing and the manufacturing of air compressors was extracted from the information gathered by conducting the above two phases of literature review. The details of conducting this literature review are presented in the subsequent sections of this paper.

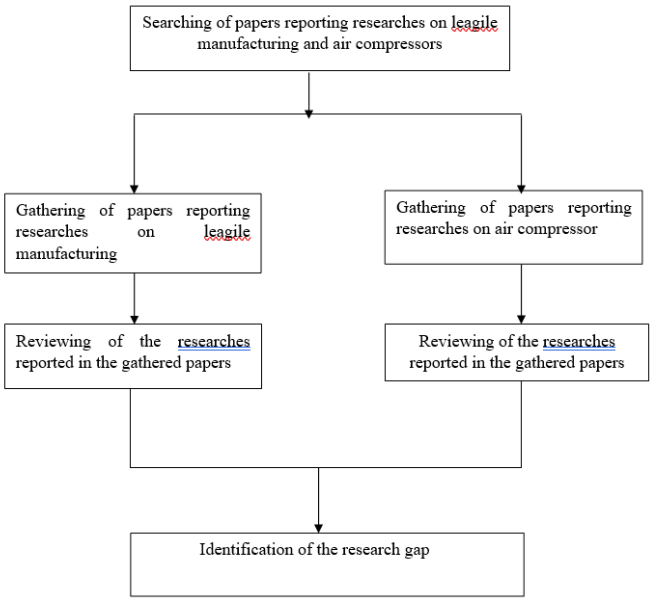

Figure 1: Research methodology

3 Researches on Leagile Manufacturing

While carrying out the literature review being reported here, the papers reporting the researches on leagile supply chain management were excluded. Instead, the papers reporting researches exclusively on leagile manufacturing were reviewed. The observation, information and knowledge derived by carrying out this literature review are presented in this section.

The origin of leagile manufacturing concept occurred in the research field with the publication of Naylor et.al. [15] which contained the seminal work on leagile manufacturing. Leagile manufacturing paradigm is incorporated with pull and push systems. When the requirement is stable and bulk, push system is followed along the supply chain. When the demand is dynamic and customized, the pull system is required to be followed along the supply chain. The point which separates the adoption of pull and push systems is called as decoupling point [25].While implementing leagile manufacturing paradigm, the decoupling point has to be chosen in such a way that the mass customization is achieved to the highest possible extent. The implementation of leagile manufacturing paradigm and benefits achieved has been narrated in Naylor et.al. [15] by describing a case study involving the supply chain of a personal computer manufacturing company. Subsequent to the publication of this paper, many researchers worked on leagile manufacturing paradigm and presented research papers which were published in various journals [26, 27]. The contents of these papers have been briefly highlighted in the following paragraphs.

Chan et. al. [28] have mentioned that leagile manufacturing approach is integrated with process planning, scheduling and outsourcing for improving the performance of manufacturing companies. An algorithm called 'Enhanced Swift Convergence Simulated Annealing' (ESCSA) was developed by incorporating the salient features of genetic algorithm, simulated annealing and a fuzzy logic controller. While concluding, it is suggested that leagile manufacturing paradigm has to be implemented in various manufacturing environments to enhance flexibility in operations and meet the modern customer requirements. Shukla and Wan [29] have reported a research on leagile manufacturing in which transshipment was applied. While conducting this research, the positioning of decoupling point was managed through the concept called postponement. In this paper, instead of postponement, transshipment was adopted. In order to achieve leagility through transshipment, a model named as 'Leagile Inventory Location Model' (LILM) was developed in this research. While concluding the paper, certain features are suggested for inclusion in LILM for making it suitable for implementation in real world scenario.

Shahin and Jaberi [19] have mentioned that postponement, mass customization and modularization are three major strategies of leagile production. A model encompassing these three strategies has been proposed. The effectiveness of this legile production model was tested by applying Six Sigma methodology. Wang et.al.[30] laid the foundation for initiating the researches under the domain named as 'leagile software development'. In the beginning of the paper, the fundamentals of lean manufacturing principles are discussed. Then, the application of these principles in software development has been appraised under two topics namely 'lean software development' and 'agile software development'.

After presenting the theory and research on lean, agile and leagile manufacturing paradigms, Matawale et.al. [31] have mentioned that it was required to identify the enablers of leagile manufacturing paradigm and establish the inter-relationship existing among them. The research carried out to fulfill this need has been presented in this paper. In this regard, a case study has been reported. While conducting this case study, the enablers of lean, agile and leagile manufacturing were identified. The technique called 'interpretive structural modelling' (ISM) was applied to establish the relationships among them.

Razmi et.al. [32] has addressed the method of enhancing the performance of organizations by infusing leagile characteristics. The situation depicted through this mathematical model is called 'a hybrid fuzzy bi-objective nonlinear programming H-FBONLP problem'. The

usefulness of this model in imparting the leagility on a facility has been demonstrated by considering a numerical example. The result of this research indicated that the proposed model has the potential to enable the engineers for identifying the activities which are required to influse the leagility characteristics in organizations.

Lemieux et al. [33] have reported a research in which a leagile transformation model for product development was developed. Increasing competition has been forcing the organizations to develop variety of products to fulfill customer needs. Some of the products require the implementation of lean manufacturing principles for meeting the requirements of the competition. Other products require the development through the application of agile manufacturing principles. This situation indicates the need to implement leagile manufacturing principles for carrying out the product development. In order to implement leagile manufacturing principles, researchers have been striving to develop transformation models. In those models, the integration of transformation activities with the strategic objectives of the organization has not been clearly addressed. Moreover, these transformation models are devoid of structured approach which is essential for achieving competitive strength . In order to overcome these deficiencies, the transformation model developed during this research was incorporated with eight capabilities. Some of them include the 'applicability through structured approach' and 'adaptable to enable the effective implementation of leagile manufacturing principles'. After developing this model, a case study was conducted in a luxury products manufacturing company. The leagile transformation model was implemented in this company by following these three stages. On implementation of this transformation model, many quantitative and qualitative improvements were achieved. Particularly, there was a reduction of 25% in the time to market of new products. Further, multi-team based activities became operational for implementing the leagile manufacturing paradigm.

Nieuwenhuis and Katsifou [25] have dealt about lean, green, agile and leagile manufacturing paradigms. These paradigms have been discussed from the point of view of enhancing the performance of automobile companies. To begin with, the way of achieving sustainability through the integration of lean and green manufacturing paradigms has been discussed. It is claimed that the environmental damages caused by the automobile industries is very high. Hence, the integrated lean and green manufacturing paradigm is required to facilitate the automobile industry for producing sustainable cars in low volume. It is mentioned that the effectiveness of applying leagile manufacturing paradigm can be enhanced through the location of decoupling point and moving the same towards the customer end. Along the upstream of supply chain, lean manufacturing is implemented. Along the downstream of the supply chain, agile manufacturing is implemented. Moving of the decoupling point towards the customer end can be achieved by applying the postponement concept. After acquiring this theoretical knowledge, the supply chain of the company called Morgen Motor was studied.

In total, the researches described in the above papers have indicated that the location, movement and positioning of decoupling point are the core aspects of implementing leagile manufacturing paradigm which will enable the companies to acquire sustainable and competitive strengths.

4 Researches on Air Compressors

A search was made in literature arena to review the researchers conducted by involving air compressors. As more than 79,000 papers reporting researches on air compressors have

appeared in literature arena, it was decided to review the papers reporting reviews of researches on air compressor. A search carried out by using 'review of researches on air compressors' resulted in the listing of seven papers. The reviews reported in these papers are briefly described in the following paragraphs of this section.

Lei et.al. [18] have reported the review of researches conducted to identify the ways of eliminating or reducing rotating stall in centrifugal air compressors. Rotating stall refers to the phenomenon of drop in pressure recovery while using diffuser or impeller in centrifugal compressors. The rotating stall occurring in centrifugal air compressors leads to pressure fluctuation and flow instabilities. These problems affect the performance of centrifugal air compressors. In order to find the solutions for overcoming the rotating stall problem, researchers have conducted analyses in four directions. While concluding, it is mentioned that rotating stall highly affects the performance of centrifugal air compressors. It has been suggested that the best injection effect is to be studied by inputting wide range of injection mass flow rate values. Further, it is suggested to study the role of diffuser in reducing rotating stall in centrifugal air compressors in real time practice.

Liang [34] has reviewed the activities that have been reported with respect to linear compressor. A conventional reciprocating compressor requires a crank to reciprocate the piston, whereas linear compressor does not require a crank and is run using electrical motor. Despite many advantages over the crank driven compressors, the linear compressor suffers from certain disadvantages. One disadvantage is the high cost of manufacturing the linear compressor, as it is incorporated with rare earth materials. Because of these disadvantages, the use of linear compressor in vapor compressor refrigeration system has been very rare. In order to avail the advantages of using linear compressors, some improvements in the designing of linear compressors have been suggested. In line to this development, a company by name Sun Power has been selling household refrigerators fitted with linear compressor. Certain challenges are yet to be overcome by the researchers and practitioners. Eleven such challenges are listed in this paper.

Li et.al.[35] have reviewed the researchers reported in literature arena in which several efforts were made to arrest the stalling in air compressors used in aero-engines. It has also been claimed that “tip air injection" was adopted by the researchers who have been striving to find solutions for preventing the occurrence of stalling in axial compressors. These researches have been carried out largely along two directions. Along one direction, the design of air axial compressors and tip air injectors for preventing the stalling effect were studied. Some of the design parameters studied by these researchers are, injected pitch angle, Coanda effect and injected yaw angle. The photograph of prototype of Coanda injector has also been presented in this paper. Though many solutions have been obtained in the researches conducted in the past, it is suggested that further researches may be conducted to derive the knowledge which can be applied to prevent the stalling effect in air compressors.

The design of the currently used air compressors is obsolete [36]. Hence, the efficiency of operation of the currently used air compressors is low and electricity consumption of the same is high. The air compressors operating at nine bar exhibit very low performance variability. Similar research has been reported in [37]. In this paper, the cost saving in electricity has been explored by replacing 'water cooled' and 'air cooled' air compressors in place of the currently used industrial compressors. The parameters namely net present value (NPV) and payback period were used for carrying out this exploration. The cost saving achievable through the

decreased electricity consumption under various conditions of replacing the existing industrial compressors with the new air- and water-cooled compressors has been presented.

The reviews presented in the above papers have indicated that researchers have been largely studying the characteristics of air compressors which are used for a long time in manufacturing world. Although these developments coincide with the development pattern of legile manufacturing, the explicit researches on implementing legile manufacturing paradigm is yet to start in air compressor manufacturing domain.

5 Connectivity between Leagile Manufacturing and Air Compressor Production

A few researchers have investigated the implementation of leagile manufacturing in automobile sector [19, 25]. This is due to the reason that during the past two decades, automobile industry has been required to deliver conventional, innovative and partially innovative products and services to the customers. Hence, spontaneously, automobile, industry has been imbibing leagile manufacturing paradigm. Further, a research on implementing leagile manufacturing paradigm in pump industry has been reported in [38]. Many researchers have worked on improving the performance of air compressor by introducing injection systems and preventing the stalling effect by suggesting design modifications [36, 37, 39, 40]. Few researchers have explored the way of reducing the electricity consumption while using air compressors. Collectively, these researches resulted in suggestions for enhancing the working of the currently used air compressors by introducing innovative features in their design. These suggestions lead to the need of developing conventional, partially innovative, and innovative air compressors. As mentioned earlier, this inference reveals the need to implement leagile manufacturing paradigm in companies manufacturing air compressors. Studying the impact of such implementation in air compressor industry is the need of the hour for producing conventional, partially innovative and innovative air compressors.

6 Conclusion

The research presented in this paper was carried out to attain three objectives. In order to attain the first objective, the meaning and essentials of leagile manufacturing paradigm had to be studied. In order to attain the second objective, the trend of researches on air compressors as reported by the researchers had to be studied. In order to attain the third objective, the research gap with regard to the implementation of legible manufacturing paradigm in the air compressor manufacturing industry had to be identified. These objectives were attained in three phases. During the first phase, the papers reporting the researches on leagile manufacturing paradigm were reviewed. At the end of this review, the knowledge on the theory and implementation of legible manufacturing paradigm was acquired. During the second phase, the papers reporting the literature reviews on air compressor were reviewed. At the end of this phase of the literature review, the state of the art researches on air compressor could be identified. During the third phase, the results of two reviews which were obtained during the above two phases of the work were analyzed. The results of this analysis indicated the research gap which needs to be filled by the modern researchers for enabling today's air compressor companies to enhance their performance for meeting not only the requirements of world level standards but also for acquiring competitive strength. The major research gap

found was the absence of research on implementing legible manufacturing paradigm in air compressor industry. Particularly, the absence of a model for implementing legible manufacturing paradigm in air compressor industry is found to be a significant research gap. Hence, it is the need of the hour for carrying out researches on the theory and practice of implementing legible manufacturing paradigm in air compressor industry.

References

[1] Virmani N, Saha R, Sahai R (2018a). Social implications of leagile manufacturing system: TISM approach. International Journal of Productivity and Quality Management, doi:10.1504/IJPQM.2018.090265

[2] Francis A, Thomas A,(2020) Exploring the relationship between lean construction and environmental sustainability: Exploring the relationship between lean construction and environmental sustainability: A review of existing literature to decipher broader dimensions, https://doi.org/10.1016/j.jclepro.2019.119913

[3] Womack JP, Jones DT, and Rose D (1990) The Machine that Changed the World, Rawson Associates; New York, NY.

[4] Abu F, Gholami H, Saman M Z M. et al (2021) Pathways of lean manufacturing in wood and furniture industries: a bibliometric and systematic review. Eur. J. Wood Prod, 79:753–772 https://doi.org/10.1007/s00107-021-01713-2

[5] Sartal A, Llach J, León-Mateos F(2022) Do technologies really affect that much? exploring the potential of several industry 4.0 technologies in today's lean manufacturing shop floors Oper Res Int J,22:6075–6106 https://doi.org/10.1007/s12351-022-00732-y

[6] Buer S V, Semini M, Strandhagen J O, Sgarbossa F(2020) The complementary effect of lean manufacturing and digitalisation on operational performance. International Journal of Production Research, 59(7):1976-1992 DOI: 10.1080/00207543.2020.1790684

[7] Oliveira D, R.I, Sousa, S O, de Campos, FC (2019) Lean manufacturing implementation: bibliometric analysis 2007–2018. Int J Adv Manuf Technol, 101:979–988 https://doi.org/10.1007/s00170-018-2965-y

[8] Virmani N, Saha R Sahai R (2017). Understanding the barriers in implementing leagile manufacturing system. International Journal of Productivity and Quality Management, doi:10.1504/IJPQM.2017.087866

[9] Gunasekaran A, Yusuf Y, Adeleye E O, Papadopoulos T, Kovvuri D, Geyi D A(2018): Agile manufacturing: an evolutionary review of practices. International Journal of Production Research,57(15-16):5154:5174 DOI:10.1080/00207543.2018.1530478

[10] Varl M, Duhovnik J, Tavčar J(2020) Agile product development process transformation to support advanced one-of-a-kind manufacturing. International Journal of Computer Integrated Manufacturing, 33(6):590-608 DOI:10.1080/0951192X.2020.1775301

[11] DeVOR R, GRAVES R, MILLS J J (1997) Agile manufacturing research: accomplishments and opportunities. IIE Transactions 29:813–823 https://doi.org/10.1023/A:1018575613893

[12] Krishnamurthy R, Yauch C A (2007) Leagile manufacturing: a proposed corporate infrastructure. International Journal of Operations & Production Management, 27(6):588-604 https://doi.org/10.1108/01443570710750277

[13] Bhamra R, Nand A, Yang L, Albregard P,Azevedo G, Corraini D (2020) Is leagile still relevant? A review and research opportunities. Total Quality Management & Business Excellence, 32(13-14):1569-1593

[14] Nayak R, Choudhary S(2020) Operational excellence in humanitarian logistics and supply chain management through leagile framework: a case study from a non-mature economy. Production Planning & Control, 33(6-7):606-621 DOI: 10.1080/09537287.2020.1834135

[15] Naylor J B, Naim, Mom, Berry D(1999) Leagility: Integrating the lean and manufacturing agile manufacturing paradigms in the total supply chain. International Journal of Production Economics, 62(6):107-118

[16] Mason-Jones R, Naylor B, Towill D R(2000) Lean, agile or leagile? Matching your supply chain to the marketplace. International Journal of Production Research, 38(17): 4061-4070

[17] Virmani, Naveen; Sharma, Vikram (2019). Prioritisation and assessment of leagile manufacturing enablers using interpretive structural modelling approach. European J. of Industrial Engineering, doi:10.1504/EJIE.2019.104293

[18] Lei Z, Ruiyang H, Songling W, Qian Z (2020) A Review of rotating stall in vavelen diffuser of centrifugal compressors. Journal of Thermal Science,doi:10.1007/S11630-020-1261-/

[19] Shahin A, Jaberi R(2011) Designing an integrative model of leagile production and analyzing its influence on the quality of auto parts based on Six Sigma approach with a case study in a manufacturing company. International Journal of Lean Six Sigma, 2(3):215 - 240

[20] Virmani, N., Saha, R. & Sahai, R. (2018b) Evaluating key performance indicators of leagile manufacturing using fuzzy TISM approach. Int J Syst Assur Eng Manag **9**, 427–439 , doi.org/10.1007/s13198-017-0687-4

[21] Balakrishnan, K.; Devadasan, S.R.; Murugesh, R. (2018). Design of leagile manufacturing system in a traditional pump manufacturing company. International Journal of Business Innovation and Research, doi:10.1504/IJBIR.2018.096367

[22] Balakrishnan, K.; Devadasan, S.R.; Murugesh, R. (2019). Design of a model for implementing leagile manufacturing paradigm in the pump industry. International Journal of Management Practice, doi:10.1504/IJMP.2019.100394

[23] Rossini M, Audino F, Costa F, Cifone, F.D, Hunda H, Portioli-Staudacher (2019) Extending lean frontiers: a kaizen case study in an Italian MTO manufacturing company. Int J Adv Manuf Technol, 104:1869–1888 https://doi.org/10.1007/s00170-019-03990-x

[24] Das B, Venkatadri U, Pandey (2014) Applying lean manufacturing system to improving productivity of air conditioning coil manufacturing. International Journal of Advanced Manufacturing Technology, 17:307-323

[25] Nieuwenhuis P, Katsifou E(2015) More sustainable automotive production through understanding decoupling points in leagile manufacturing. Journal of Cleaner Production, 95(15):232-241

[26] Virmani N, Saha R, Sahai R(2018c). Leagile manufacturing: a review paper. International Journal of Productivity and Quality Management, doi:10.1504/IJPQM.2018.089807

[27] Piotrowicz W D, Ryciuk U, Szymczak M (2021) Lean and agile metrics. Literature review and framework for measuring leagile supply chain. International Journal of Productivity and Performance Management, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJPPM-10-2020-0560

[28] Chan F T S, Kumar V, Tiwari M K(2009) The relevance of outsourcing and leagile strategies in performance optimization of an integrated process planning and scheduling model. International Journal of Production Research, 47(1):119-142

[29] Shukla S K, Wan H D (2010) A leagile inventory–location model: formulation and its optimisation. International Journal of Operational Research, 8(2):150 - 173

[30] Wang X, Conboy K, Cawley O (2012) "Leagile" software development: An experience report analysis of the applicationof lean approaches in agile software development. The Journal of Systems and Software, 85:1287–1299

[31] Matawale C R, Datta S, Sankar S, Mahapatra (2013) Interrelationship of capabilities/enablers for lean, agile and leagile manufacturing: an ISM approach. International Journal of Process Management and Benchmarking, 3(3):290-313 DOI:10.1504/IJPMB.2013.058157

[32] Razmi J, Hassani A, Babazadeh R(2014) A hybrid fuzzy bi-objective delivery planning model for leagile e-tailing under uncertainty. International Journal of Management Science and Engineering Management, DOI: 10.1080/17509653.2014.962110

[33] Lemieux A A, Lamouri S, Pellerin R, Tamayo S(2015) Development of a leagile transformation methodology for product development. Business Process Management Journal, 21(4):791 - 819

[34] Liang K (2017) A reviews of linear compressors for refrigeration. International journal of refrigeration. 84:253-273

[35] Li J, Du J, Nie C, Zhang H (2019). Review of tip air injection to improve stall margin in axial compressors. Progress in Aerospace Sciences, doi:10.1016/j.paerosci.2019.01.005

[36] Vittorini D, Cipollone R(2016 a) Energy saving potential in existing industrial compressors. Proceedings of the ICE-Energy, 102:502-515 DOI:10.1016/j.energy.2016.02.115

[37] Vittorini D, Cipollone R(2016 b) Financial analysis of energy saving via compressor replacement in industry. Energy, 113:809-820

[38] Balakrishnan K, Devadasan S R, Thilak V M M, Selvi Soundaram D (2020)Leagile manufacturing paradigm in the production of jet pump – an implementation experience. International Journal of Productivity and Quality Management, 30(4):462 - 487

[39] Azizi MA, Brouwer J (2017), Stall/surge dynamics of a multi-stage air compressor in response to a load transient of a hybrid solid oxide fuel cell-gas turbine system , doi.org/10.1016/j.jpowsour.2017.09.010

[40] Shi, L. I. U., HUANG, Z., Yaxuan, H. U., Yi, Y. A. N. G., Qingshui, G. A. O., ZHANG, C., ... & Zhigang, L. I. U. (2020). Brief analysis on surge phenomenon and anti-surge technology of air compressor. *Energy Storage Science and Technology*, *9*(S1), 70.