ABSTRACT

Manufacturing is the backbone of any industrialized nation and it plays a pivotal role in the global economy. The word ‘manufacturing’ is derived from the Latin word ‘manufactus’ which means ‘made by hand’. The basic manufacturing processes are metal casting, metal forming, metal joining or metal cutting Metal castings are manufactured in foundries. The word ‘foundry’ is derived from the Latin word ‘fundere’ which means ‘melt and pour’. Metal casting, a 12,000 years young technology, offers the widest variety of routes to produce cast components in a wide range of shapes, sizes, alloys, quantities and quality requirements. There are around 50,000 numbers of foundries globally producing annually about 100 million metric tons of metal castings worth about US $ 290 billion, employing 2 million people directly and having US $ 30 billions exports with annual incremental growth rate of 3 million metric tons and adding around 50 number of new foundries every year.

Holonic manufacturing systems (HMS) have been evolving from intelligent manufacturing system for product development, manufacturing and shopfloor controls. The main objective of HMS is to explore mechanisms for cooperation among industrial enterprises, universities/ institutes and research organizations globally with the aim of promoting research in and adoption of holonic technologies for manufacturing systems in order to meet the diverse customer requirements like shorter lead times, higher productivities, large product varieties and lower cost without concessions on quality.

The holonic casting manufacturing approach is based on a concept of the ‘holon’ introduced by Koestler. The word ‘holon’ is the combination of Greek word ‘holos’ meaning ‘whole’ with suffix ‘on’ which suggests a ‘particle or part’. From the literature survey it is found that not much of research work seems to have been carried out in holonic manufacturing systems for foundries. Hence in the present work an attempt has been made to contribute to fill this gap.

Any new technology developed by researchers should be technically feasible, economically viable, socially acceptable and environmentally friendly and it should also improve productivity, profitability and total quality. When these conditions are fulfilled the application domains can be identified and feasibility studies carried out considering a suitable real industrial scenario. In the present research work an attempt has been made to address some of these aspects related to foundry industry.

The major objectives of this research include productivity studies of global foundry industry, European foundry industry, top ten world casting producing nations, Indian foundry industry and melting section of a foundry. The studies also include various economic analysis of cylinder block/ head castings.

Development of a framework of holonic casting manufacturing system (HCMS) and its sub-systems for foundries, analysis of total transport work for a gray iron, and development of transportation holon was considered. Estimation of the economic benefits derived from this work and a migration schedule (time schedule) for holonic systems were discussed. The study also includes identification of Internet based Induction Furnace Product Resource Order Staff Holon Agent (IIFPROSHA) architecture and its sub-systems.

The status of global foundry industry and its sub-systems, labour cost and casting value indices based on USA and India, cluster wise foundry industry synthesis, economic analysis and case studies on global die casting industry, casting process development, and casting production economics of foundries of Western India were also included.

Development of a step wise mathematical procedure and its sub-systems for casting process selection using analytical hierarchy technique by pair wise comparison for multi-process and multi-attribute decision making for shop floor environments was done. Universal casting genetic map for foundry industry and casting genome for cylinder block and head castings was developed. The major findings from the present work are as follows.

Global casting productivities of various countries were varying from 15.8 (India) to 97.33 (Japan) tons per man year and the global average was found to be around 34.16 tons per man year. Annual productivity per foundry site was varying from 672 (India) to 6,610 (Germany) tons and the global foundry average was around 2036 tons. Clusterwise productivities were varying from 25.7 (Asia Pacific Foundry Cluster) to 57.7 (European Union Foundry Cluster) tons per man year and that of average per foundry individual site from 1390 (Latin America Foundry Cluster) to 3450 (European Union Foundry Cluster) in tons per year. Casting productivity of EUFC was found to be around 89.1 tons/man year in France and the minimum was 20.9 tons/man year in Hungary. The non-ferrous casting productivity was varying from 5.6 ton/man year in Hungary to 34 tons/man year in Belgium.

Labour productivity of melting section of a typical automotive foundry was varying from 6.91 to 12.78 in the morning shift whereas in the evening shift it was varying from 8.64 to 12.86 in tons per man-month. The average productivity for nine months period was found to be around 10.29 ton per man-month. The morning shift specific power consumption per ton of metal melted was varying from 537 to 1417 kWh whereas in the evening shift specific power consumption was varying from 409 to 1250 kWh per ton. The parametric analysis (defect percentage, casting yield, cycle time, costs) for cylinder block and head castings was done based on the shopfloor data of a gray iron foundry.

The present research work includes identification and development of taxonomy of foundry holons and its sub-systems, defining basic concepts and architecting principles of holonic casting systems, development of Internet-based Induction Furnace Product Resource Order Staff Holon Agent (IIFPROSHA) architecture, selection of holonic casting test-bed, identification of melting holon and its sub-systems, and a transportation holon for a working foundry. The work also highlights evaluation of performance metrics for three types of foundries, migration schedule and cost benefits analysis.

IIFPROSHA architecture was developed for 3,000 tons per annum capacity foundry for manufacture of cylinder block and cylinder head castings. The proposed holonic casting test-bed consists of five work stations for induction melting, moulding, lost foam casting, sand plant, and robotic fettling. A working gray iron foundry was selected for performance metrics analysis and feasibility study for holonic application domains for process parameters improvements (productivity, power consumption, cycle time, shop floor area required, man power and man hours required). Three different foundry systems and equipments required, cost benefits derived were also outlined. An AGV transportation holon (four AGV holons, order holon and staff holon) was considered for the movement of moulds and lost foam patterns and for pouring metal in the work stations. Holonic casting manufacturing system migration schedule was developed. The cumulative time required is 245 days and 11,760 engineer-hours for implementation.

Global foundry industry value analysis and its sub-systems (global casting value indices, identifying top ten performers, global foundry clusters, alloywise casting production change, prediction of casting production for global, China and India, Indian casting production and dollar value, and global foundry labour cost) were done. Finally labour indices were developed for global foundries with base as India (100) and United States of America (100). Casting value indices (CVI) and casting production indices for top ten casting producing nations and the world were computed based on India and USA. It is interesting to note that the countries like Mexico (1.4), Italy (1.5) had the highest CVI as compared to the highest casting producing nations like China (0.8) and USA (1.0).

Casting process selection by analytical hierarchy technique for cylinder block/ head casting was developed considering five casting processes and fifteen attributes and it was found that lost foam casting process got the highest priority weight (0.6267) followed by die casting (0.3176), gravity casting (0.1523) and sand casting (0.0989).

In the present work a universal casting genome map consisting of casting chromosomes (W,X,Y,Z), genes (A,B,C,D,E,F,G,H,I,I,J,K) and codons (many) for foundry industry was developed. Casting codon arrays for cylinder block/ head castings made of gray iron and aluminium silicon alloy were also presented.