International Journal of Research in Advent Technology, Special Issue, ICIMCE 2019
E-ISSN: 2321-9637
Available online at www.ijrat.org

Design For Excellence (Dfx): A Tool For Improvements In Manufacturing Systems

[1]Bhilare Ram B., [2]Kolekar Kailas B.
[1]Student of Mechanical Eng., [2]Assistant Professor,
DYPIET, Ambi, Pune,India 410506
rambhilare5@gmail.com,kkailas03@gmail.com

Abstract: Customer needs and product specifications are the basic guidelines in the concept phase of product design and development. However, during the post design activities in manufacturing, testing and production, development teams often have difficulty to link specifications to the product and many times they face specific design issues. For this reason, many design engineers practice so called "design for X" (DFX) methodologies, where X may correspond to one of many quality criteria, from more general, such as manufacturability, appropriateness for assembly, reliability, robustness, and maintainability, to more specific, like environmental impact, ergonomic and aesthetic value, etc.

This article gives an overview of research that is expanding the domain of DFX i.e. design for manufacturing, assembly into new and important areas. The paper covers DFX for conceptual design, DFX for detailed design, design for production, platform design for reducing time-to market, design for system quality, design for costs, and design for environment.

This article discusses the fundamental concepts, advanced techniques, and theory of DFX with the key benefits of implementing it. The case study included here discusses the benefits of DFX guidelines which are practically applied in a die-casting industry. These techniques proved a very impressive tool to improve the manufacturing with reduction in costs and improvements in quality.

Key words – Design for X (DFX), DFM, DFA, DFMA, Quality Improvement, DFP, DFS

1. INTRODUCTION:

Design for excellence or DFX is a systematic design approach that entails wide range of guidelines and standards focused on optimizing the product realization lifecycle in reality. These guidelines ensures the issues related to manufacturing, cost, quality, assembly and serviceability are addressed at the design stage itself. If these guidelines are not adhered during the design stage, it can lead to engineering changes occurring at later stages of product lifecycle, which are highly expensive and can cause product delays and cost over-runs through rejections and rework.

Developing successful new products requires the ability to predict, early in the product development process, the life cycle impact of design decisions. Downstream life cycle issues include considerations of how the product will be manufactured, assembled, shipped, installed, used, serviced, and retired or recycled. Ignoring downstream issues leads to poor product designs that may cause unforeseen problems and excessive costs. Sometimes, when problems are uncovered during design verification or testing, the problems may be addressed by redesign. The cost at this redesign stage is prohibitive type. If accurate predictions of life cycle needs can be made early in the design cycle, it allows product development teams to create superior designs. This not only reduces the number of redesign iterations, the time to market, and the development and manufacturing costs but also improves the customer’s experience [2, 9].

2. OBJECTIVES OF DFX:

- To simplify design.
- To reduce cost of product.
- To minimize complications in production, assembly, manufacturing, safety and service.
- To become competitive in market.
- To avoid rejection and reworks in later stages of manufacturing and production.
- To improvement quality
- To improve reliability and robustness of product. [6,9]

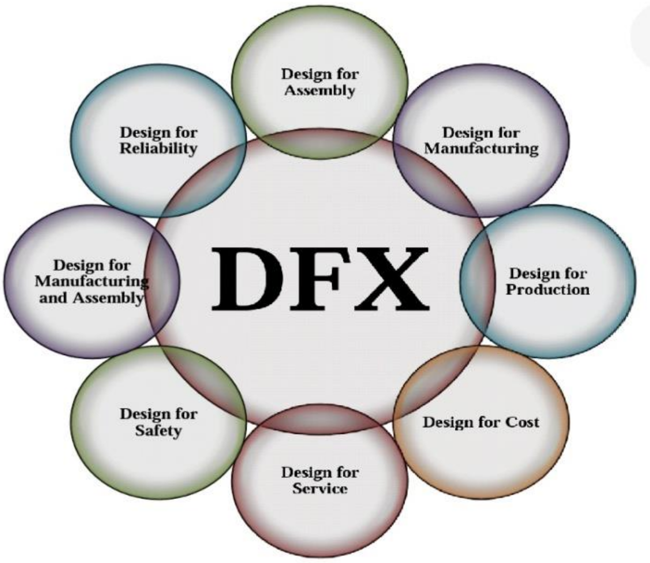


Fig No: -1 DFX Methodology [9]

3. SOME OF THE MOST COMMON SUBSTITUTES FOR X INCLUDES:

- Design for manufacturing (DFM)
- Design for assembly (DFA)
- Design for manufacturability and assembly (DFMA)

4. DESIGN FOR MANUFACTURING:

DFM is the method of design for ease of manufacturing of the collection of parts that will form the product after assembly. DFM is a design practice, considering product manufacturing constraints during design and development stage itself. Successful DFM implementation results in lower production cost, improving product performance, without scarifying product quality. [6,9]

DFM Method:

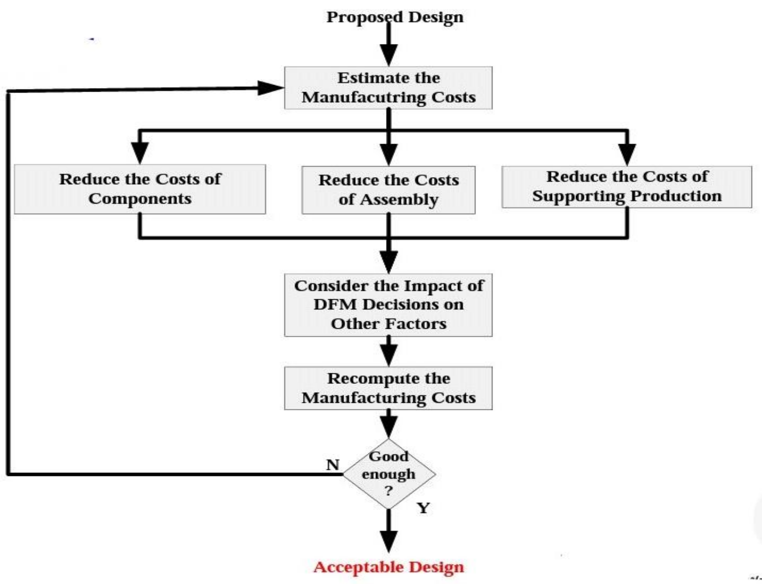


Fig. No: 2 DFM Method [9]

5. DESIGN FOR ASSEMBLY:

DFA is the method of design of the product considering the future assembly of all the components of the product.

DFA Principles:

- Minimize part count
- Design parts with self-locating features
- Design parts with self-fastening features
- Minimize reorientation of parts during assembly
- Design parts for retrieval, handling, & insertion
- Emphasize ‘top-down’ assemblies
- Standardize parts
- Minimum use of fasteners
- Encourage modular design

- Design for a base part to locate other components
- Design for component symmetry for insertion [6,9]

6. DESIGN FOR MANUFACTURABILITY AND ASSEMBLY (DFMA):

DFMA stands for Design for Manufacture and Assembly. DFMA is the combination of two methodologies; Design for Manufacture (DFM), which means the design for ease of manufacture of the parts that will form a product, and Design for Assembly (DFA), which means the design of the product for ease of assembly.

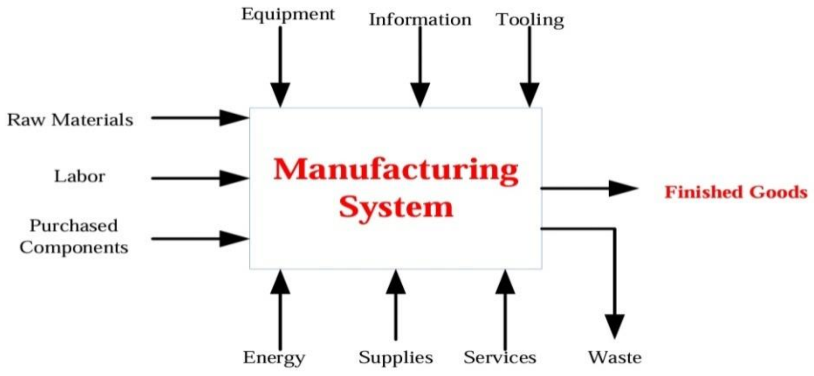


Fig No 3: Manufacturing System considering DFMA [9]

7. IMPACT OF DFX ON COST OF PRODUCT:

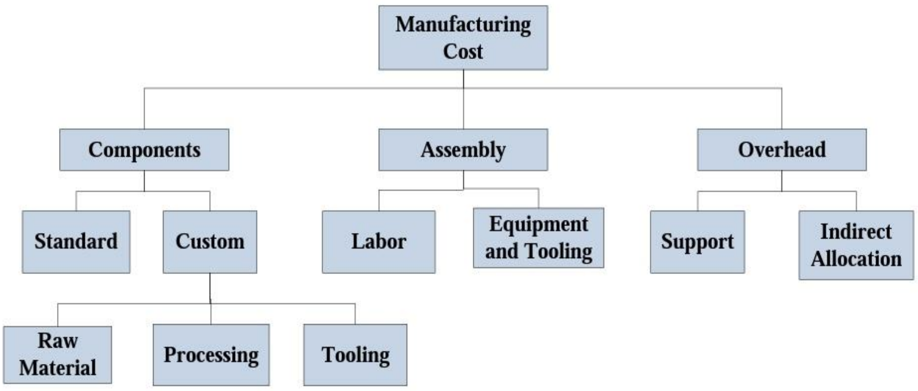


Fig No 4: Costs associated with product [9]

Designing for cost is the conscious use of engineering process technology as directed in DFM, DFA & DFMA principles, to reduce life cycle cost. Fig. No. 5 exhibits the cost benefits of DFX.

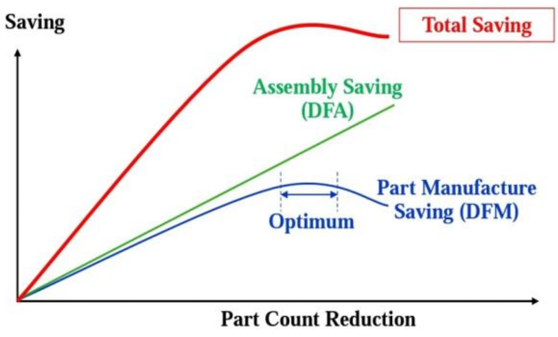


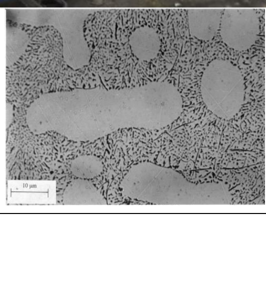
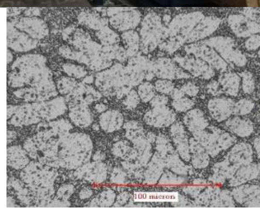
Fig. No. 5 : Cost Benefits of DFX [9]

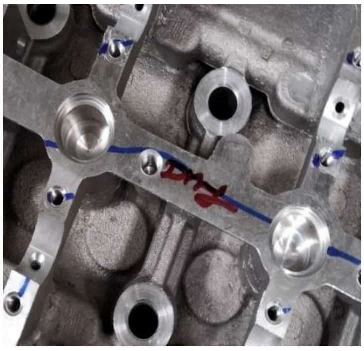
8. BENEFITS OF DFX:

- Product design for manufacturability
- Improved yield, performance and cost
- Improved assembly yield and reduced labour content
- Product design for testability
- Improved coverage, reliability and final yield, reduced and field failures.
- Reduced development engineering resource commitment, improved time to market
- Product/ process stability and repeatability
- Reduced lead time, improved availability / lifecycle and material costs
- High quality, reliable and robust performance for the life of the product capability
- Improved production stability and predictability
- First pass yield and capacity
- Continuous improvement & the competitiveness measures & improvement and rationalization decisions in designing products, process, and resources.
- Quality improvements, lead time reduction, product risk reduction, and product material cost reduction. [6,7,9]

9. CASE STUDY ON APPLICATIONS OF DFX:

This case study represents applications of DFX techniques for improvements in manufacturing and reduction in overall cost of production. The DFX guidelines are applied in a die-casting industry located in nearby area of Pune, India. Based on the previous experiences of defects in similar components of die-casting and problems encountered in production trials in development stage of these components, some corrective actions are taken during design stage and sample manufacturing itself. It is found that implementation of DFX principles during the design stage and sample manufacturing stage proved beneficial to the industry. This exercise saved a considerable amount of rework time and costs associated with it. Below is the list of some modifications done based on DFX during sample manufacturing, testing and redesign stages:

Sr. No.	Description	Problems encountered during production trials	Improvements after applications of DFX Principles
1.	The wall thickness of cylinder head at initial design stage was 2 mm. However, during die-penetration test some cracks on the surface of water jacket were observed. Hence, the wall thickness of cylinder head was revised as 3mm during redesign stage and it is observed that the problems of cracks are eliminated.		
2.	Cooling of dies: The design of die cooling set is modified with increase in number of ports for water jet to incorporate higher cooling rate for dies. Earlier, due to low cooling rate of dies defect of dendrites was observed. Thus design modifications in die cooling set proved helpful in controlling the defects in SDAS.	 	 

3	The internal surface of water jacket was found rough during the inspection of sample cylinder head. The rough surface may cause the rusting of internals of cylinder head. Hence during the review of the design it is decided to replace the coarser core sand with fine core sand to get smoother surface.		
4.	Porosity was the major problem observed and it is found that it is occurring because of less time of degassing of hydrogen. During the testing and redesign stage it is observed that if we increase the time for degassing, the porosity will decrease resulting in decrease in density. After some trials, the time is set and the problem of porosity is eliminated.		
5.	During the manufacturing trial, air bubbles were observed in the molten metal while pouring it. While analysing the problem, it is concluded that the core burns during pouring and gases are generated due to burning and these gases forms bubbles. To overcome this problem, injection core is redesigned with providing holes to escape the gas formed during pouring. Due to this redesign, the problem is eliminated.		
6.	Scratches were observed on the surface of casting during the removal of sample casting at the time of trials. This was due to low draft. During the redesign process the problem of scratches is overcome by increasing the die draft by 10% of originally designed draft.		

10. CONCLUSION:

The DFX tools and techniques are very much applicable in every operation in manufacturing industry. This article has focused on most common DFX tools. The main benefits of applying the DFX tools are improvement in product design and performance with reduction in manufacturing costs and ultimately improving the quality of product. Also, the time and money wasted in rejections and rework are considerably saved.

In the case study included in this research article, many of the DFX techniques are applied for die casting process. For the case study discussed, it can be concluded that if we apply DFX techniques during the design and testing phase itself, the less trouble will be there during manufacturing. It has helped to avoid future defects and problems in productions improving the quality and avoiding the further wastes and costs associated with these wastes which may have incurred further at production time.

ACKNOWLEDGEMENT:
The authors are thankful to the authorities in Design Department and Quality Assurance Department of the Die Casting Industry mentioned. The Author is part of team for Quality Assurance of the Die-Casting Department.

REFERENCES:
[1] Abla C.B., Imane B. & Asmaa B. & Oussama Benghabrit (2019) A systematic review of design for X techniques from 1980 to 2018 concepts, applications, and perspectives.
[2] Baptista A.J. ,Peixoto D. ,Ferreira A.D. ,Pereira J.P.(2018) Lean Design-for-X methodology: Integrating Modular Design, Structural Optimization and Ecodesign in a machine tool case study Procedia CIRP Vol. 69 722 – 727
[3] Barder A. ,Gebert K., Hogrive S. ,Tracht K. (2018) Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra Procedia Manufacturing Vol. 19 143–147
[4] Bojan D., Intelligent Design for X (2007) Proceedings of the 7th WSEAS International Conference on Systems Theory and Scientific Computation, Athens, Greece, August 24-26, 2007 211
[5] Christer E. , Torgeir W. Henrik V. D.(2015) Continuous improvement of technical systems using Design for X 2015 10th System of Systems Engineering Conference (SoSE)
[6] Kuo T C, Zhang H C, (1995), Design for Manufacturability and Design for X: Concepts, Applications & perspectives, Conference paper, IEEEiCPMT Int'I Electronics Manufacturing Technology Symposium, 446 – 459.
[7] Marco A. , Nicola S., Federico A.,(2017) A Design for X framework for PSS business models publication at:
Product Lifecycle Management. Vol. 3. No. 4. pp. 261–278 Nicole M.R. , Morgan C. Banton Design for X (DfX) in the Internet of Things (IoT) (2017)
[8] Poul A., Apostolos P., Kai L., David J.S.(2009) State of the art report on design for X publication at Conference :International marine design ,At Trondheim ,Volume 10
[9] NPTEL Course "Product Design and Development", (2019) By Dr. Indradeep Singh, Department of Mechanical Engineering and Industrial Engineering, IIT Roorkee.