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A Study on Costing Guidelines for Manufactured Precision Casted Parts

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Abstract

Costing of manufactured precision parts is researched earlier, though a generic costing guideline that suits multiple setup types and universal applicability is still to be evaluated. The author tends to introduce a proposal for generic cost estimation of precision parts (Castings) for the utilization of estimation engineers and technical buyers in the mechanical precision engineering industry. Process of manufacturing different types of Castings (Investment, Die & Yellow Metal) is studied along with components to relate and validate the proposed costing guidelines based on parameters (cost elements & allocations). A review would lead to the validation of proposed costing guideline through survey and discussions with experts. The costing guidelines are developed based on prior experience, expert discussions, and quotations from multiple manufacturers. Manufacturers and technical experts believe that the cost allocation against cost elements and the range proposed are very much valid to evaluate and estimate cost of casted parts in design and development stage. The results of this study will provide the guideline to establish a reference target cost for bids and quotation process done by buyers.

Keywords- Costing Guideline, Manufacturing Process Flow, Investment Castings, Die Castings, Cost Elements, Cost Allocation

1. Introduction

Multiple times in business situations engineering parts buyers face difficulty in estimating the prices of casted manufactured parts and find it difficult to validate the quotations received from manufacturers. There may be traditional approaches to costing guideline prices and validate quotations, though, I intend to propose generic costing guidelines to do the same. In doing so, costing guidelines are proposed based on experience, expert inputs and validated through limited component examples.

Generic costing guideline would provide the base to allocate costs to each cost element and guide on the method to evaluate these costs. Engineering Buyers would prefer to have costing guideline data ready before going to a negotiation. The costing guideline enables the buyer to do fact based targeted negotiations rather than comparing multiple quotes and awarding business to supplier with the lowest quotes. This would also help manufacturers to understand the target and range of pricing expected by the buyer and quote in a more structured and scientific way with transparency in costs incurred.

For organisations these costing guidelines would be references to evaluate new product development projects from beginning and serve them with a database that helps for future evaluations. Business decisions would have input cost estimates in advance and product development engineers would put efforts on feasible programs rather than spending too much time on unviable projects that don't get approved at later stages.

2. Literature Review

Costing can be done through multiple methods like Intuitive, Analogical, Analytical and Parametric. (Ben-Arieh & Qian, 2003; Niazi et al., 2006) discuss and explain these methods. Intuitive Costing is based on experience of subject matter experts and utilizing that knowledge to systematically arrive at cost estimates. Survey, expert discussions and inputs are used in the process. Analytical costing is fragmenting the production process, activities and defining cost elements that when summed up provide the total cost. Analogical costing is based on historical data and its statistical analysis. Parametric costing is expressing cost statistically as a function of its constituent variables.

Costing guidelines proposed in this paper are Intuitive and to some extent analytical based on experiences, expert discussions, and manufacturer inputs. Though, the proposals are arrived after studying multiple research papers and publications. It's important to study various manufacturing processes of Investment castings, die castings and yellow metal castings. Equally important are other elements of cost.

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Major types of metal casting methods like Investment castings, die castings and yellow metal castings are studied in this paper. Investment casting as a process also known as lost wax casting process (Mandolini et al., 2020) (Pattnaik et al., 2012) uses tree of wax patterns that are shelled by coating, then heated to dewax and metal is poured in the shell to form intricate shaped castings. Design for manufacturing and assembly (DFMA) as explained in Boothroyd et al., 2011 serves as the guiding reference while understanding the Investment casting process. Die casting (Chienwichai et al., 2016; Nagahanumaiah et al., 2005) is a process in which molten metal is poured into a die with pressure to form into a shape as designed that solidifies and becomes a part. Specific costing guidelines for Yellow metals casting is discussed and its process is studied. Yellow metals castings are manufactured using permanent moulds (Chougule & Ravi, 2006; Shelar et al., 2022). A Permanent mould is a set of Dies that has cavities to enable molten metal flow. Molten metal solidifies and shapes as a part. The difference between permanent mould and dies casting is just due to the speed and pressure at which the metal is poured.

3. Proposed Costing guidelines

Costing guidelines are detailed breakdown of costing of a product or solution. In the proposal here, we would discuss costing guidelines for select types of Castings (parts). Knowledge gap exists in generic cost structures or costing guidelines for engineered manufactured parts.

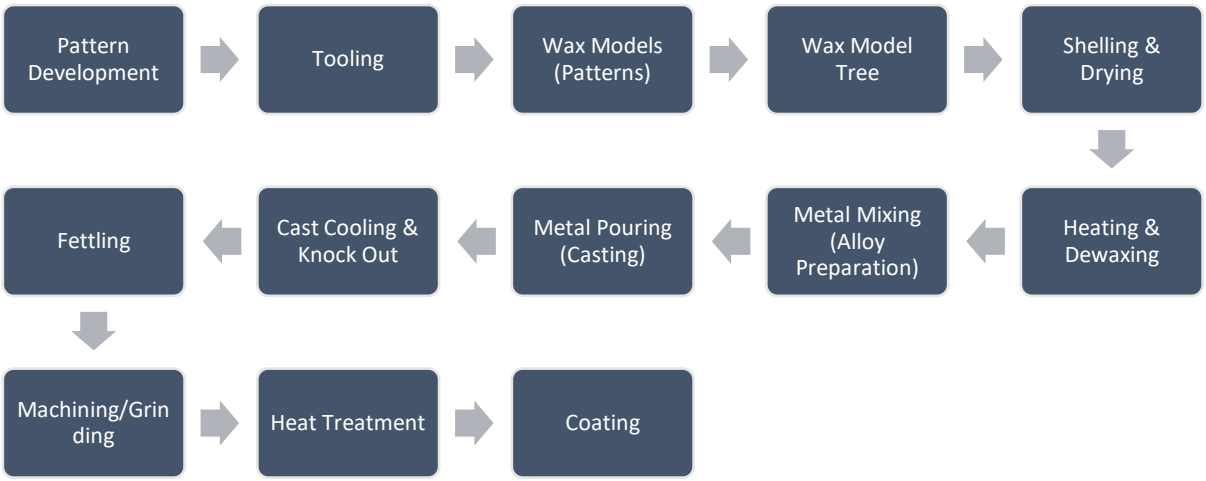
3.1 Casted Parts:

Engineered parts that are made by the process of Casting (Chougule & Ravi, 2006) - A manufacturing process in which molten metal is poured into a cavity (mould) that holds the metal to a specific shape as it solidifies.

3.1.1 Investment Castings:

Investment casting(Mandolini et al., 2020) is a metal forming process based on lost-wax casting and is one of the oldest known process of casting steel. The term investment means that the wax pattern is invested to be lost after the refractory material dries up and takes shape. As soon as the refractory material dries up, its heated and molten steel is poured and then air cooled before being sent for shell removal and fettling.

Figure 1: Investment Casting Process Flow (Source: Author's own compilation)



Each part from the casting tree is cut and then sent for basic machining and annealed. After annealing these parts are machined as per specifications and sent for further heat treatment and finishing. Cost of process and material at each stage along with other costs (labour, energy, other materials, overheads, wastage, etc) must be considered to arrive at final costing of each step.

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Investment casting parts are of intricate shapes and may require advance machining and surface treatments that makes these parts costly depending on application. Though a first-hand cost estimation is very efficient tool to evaluate feasibility of component for making business decisions. Each cost element is captures in the cost costing guideline proposed in table below.

Proposed Costing guideline for Investment Casting:

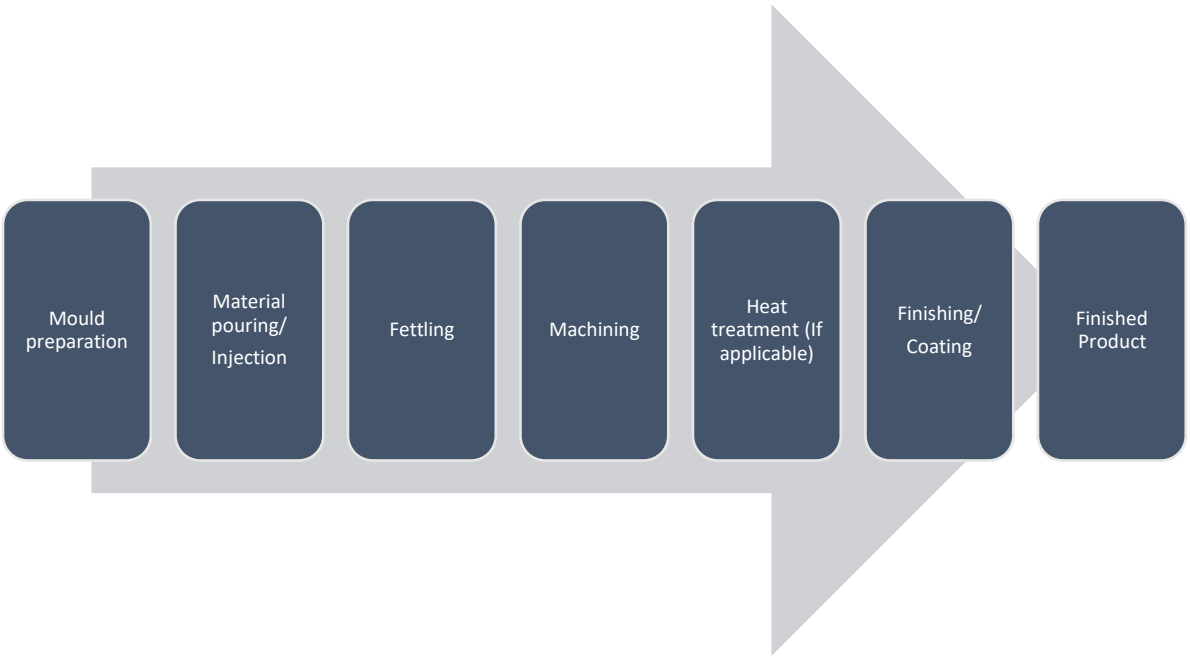
Cost Elements	Contribution
Raw Material	30~35%
Wax Injection	4~7%
Shelling	8-13%
Pouring	6~8%
Fettling	2~3%
Machining	14-18%
Heat Treatment	11~16%
Finishing	3~5%
Overheads and Profit	10~13%
Packing	1~2%

(Source: Author's own compilation)

3.1.2 Die Castings:

Die casting (Nagahanumaiah et al., 2005) (Chienwichai et al., 2016)is a metal casting process primarily used for non-steel alloys like Aluminium alloys that are poured through gravity or pressure inside a mould to take desired shape. This process is fast and the part is available for further processing quickly compared to the cyclic and time taking process of investment castings. Aluminium alloys, Zinc alloys and many expensive materials are casted using this process.

Figure 2: Die Casting Process (Source: Author's own compilation)



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Proposed Costing guideline for Die casting:

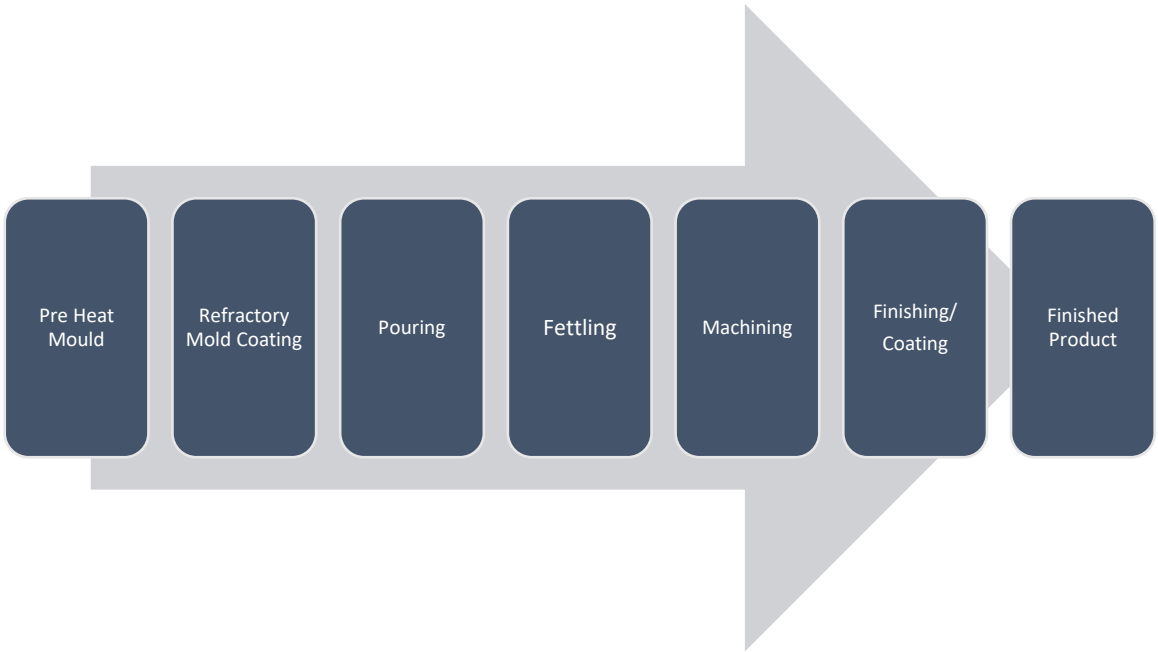
Cost Elements	Breakup
Raw Material	15-25%
Process	10~15%
Fettling	2~3%
Machining	25~30%
Heat Treatment (When applicable)	2~3%
Finishing	14~18%
Overheads and Profit	14~17%
Packing	1~2%

(Source: Author's own compilation)

3.1.3 Yellow Metal Castings:

Permanent mould Casting of yellow metals such as Aluminum-Bronze, Bronze & Brass, etc is termed Yellow Metal Castings. These are special castings and costing is key due to high cost metals like Copper used as a material.

Figure 3: Yellow metal casting Process (Source: Author's own compilation)



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Proposed Costing Guideline for Yellow metal castings:

Cost Elements	Contribution
Raw Material	20-30%
Process	7-10%
Fettling	4~6%
Machining	40-50%
Heat Treatment	0~1%
Finishing	2~3%
Overheads and Profit	13~15%
Packing	1~2%

(Source: Author's own compilation)

4. Research Methodology

Methodology adopted is qualitative and exploratory to propose a conceptual, generic though universal Costing guideline. A detailed Literature review is carried out and intuitive (Niazi et al., 2006) and to some extent analytical costing guideline based on experience and expert inputs is proposed.

A specific business unit of an industrial packaging firm was identified that uses different types of casted parts for assembly of its manual hand tools. Representative parts of each type of casting was identified to complete the study and provide evidence of cost allocation as proposed in the costing guidelines. Manufacturers of each type of casting was identified to do a random survey and seek inputs on allocation of cost against each element.

4.1 Objective of Study:

The objective of this study is to review and relate the evidence for cost allocation as proposed in the costing guidelines.

4.2 Data collection and sample size*:

- ✓ Investment Casted Parts:
- Investment Casting Parts – 2 representative samples
- Investment Castings manufacturer – 2 manufacturers
- ✓ Die Casted Parts:
- Die Casting Parts – 2 representative samples
- Die Castings manufacturer – 2 manufacturers
- ✓ Yellow Metal Casted Parts:
- Yellow Metal Casting Parts - 2 representative samples
- Yellow Metal Castings manufacturer – 1 manufacturer

*Sample size is smaller and intended only for reference to review and study the costing guidelines.

4.3 Limitations:

This is an ongoing study and intent of author is to expand the research base in future to propose Cost models. Proposals are Intuitive Costing guidelines based on experiences and expert discussions. At this point only few representative parts and manufacturers were engaged to validate the proposals.

Further, there are only limited professional manufacturers of castings due to significant capital infusion required in machinery and equipment. Parts can be unlimited as every now and then new parts are designed. Representative sample size of 2 was considered for this study.

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5. Results & Discussions

5.1 Investment casting parts:

Two manufacturers were identified as they specialize in producing investment castings. The facilities are in Rajkot & Nasik respectively. Two parts were identified for quotation from both manufacturers and the results came close in the percent allocation as summarized in table below. One of the major findings was that machining has a significant contribution in costing of investment cast parts as the material is different steel grades. Machining of tool steel investment castings is even costlier due to hardness and other properties. Though, as we are focussing here on cost we will stick to general considerations on mass produced materials.

*Details of manufacturers and parts are not included due to confidentiality associated with the product designs.

Specific meetings were completed to cross check the responses received from manufacturers and the results were concurred by technical specialists.

Table: Summary of survey responses – Investment castings

Cost Elements	Cost Breakup (Part 1) (Manufacturer 1)	Contribution (Part 1) (Manufacturer 1)	Cost Breakup (Part 1) (Manufacturer 2)	Contribution (Part 2) (Manufacturer 2)	Cost Breakup (Part 2) (Manufacturer 1)	Contribution (Part 2) (Manufacturer 1)	Cost Breakup (Part 2) (Manufacturer 2)	Contribution (Part 2) (Manufacturer 2)
Raw Material	42	30%	51	32%	56	30%	54	31%
Wax Injection	7	5%	10	6%	9	5%	9	5%
Shelling	14	10%	19	12%	19	10%	18	10%
Pouring	10	7%	11	7%	13	7%	11	6%
Fettling	3	2%	3	2%	4	2%	4	2%
Machining	21	15%	24	15%	28	15%	26	15%
Heat Treatment	18	13%	19	12%	24	13%	26	15%
Finishing	7	5%	4	3%	9	5%	6	3%
Overheads and Profit	16	12%	17	11%	21	12%	19	11%
Packing and forwarding	2	1%	2	1%	3	2%	3	2%
Total	**140**		**160**		**185**		**176**	

(Source: Author's own compilation)

Responses re-assure that the cost allocation percent range taken up in the costing guideline is close to the proposal.

5.2 Die Casting Parts:

Two manufacturers for Aluminium Die Castings (Gravity Die Casting) based out of Sonepat and Bangalore were identified for quotation on same part. One manufacturer provided detailed response on phone. The other manufacturer indicated about percent allocation on phone conversation and shared total cost only. With the help of % allocation provided by him; I was able to derive the breakup. Discussions were held with internal technical team and buyers of the packaging tools division to review the cost breakup and they concurred the response from the manufacturers.

Table: Summary of survey responses – Die Castings

Cost Elements	Cost Breakup (Part 1) (Manufacturer 1)	Contribution (Part 1) (Manufacturer 1)	Cost Breakup (Part 1) (Manufacturer 2)	Contribution (Part 2) (Manufacturer 2)	Cost Breakup (Part 2) (Manufacturer 1)	Contribution (Part 2) (Manufacturer 1)	Cost Breakup (Part 2) (Manufacturer 2)	Contribution (Part 2) (Manufacturer 2)
Raw Material	115	16%	125	17%	80	18%	85	18%
Pouring Process	80	11%	75	10%	50	11%	65	13%
Fettling	18	3%	15	2%	10	2%	10	2%
Machining	230	33%	245	33%	145	33%	150	31%
Heat Treatment (If applicable)	15	2%	20	3%	10	2%	15	3%
Finishing	115	16%	110	15%	85	19%	80	16%
Overheads and Profit	117	17%	140	19%	55	12%	70	14%
Packing and forwarding	10	1%	15	2%	10	2%	10	2%
Total	**700**		**745**		**445**		**485**	

(Source: Author's own compilation)

Machining and surface improvement (finishing) process are major contributors to the costing of Aluminium die casted parts. Other processes like High pressure die castings and Low pressure die castings require additional capital. Though, they don't directly lead to higher cost contribution due to efficiency increase in the pouring process.

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5.3 Yellow metal casting parts:

Yellow metal casting process is complex and only few organised manufacturers with permanent mould casting capabilities exist in this space. One supplier based out of Bangalore provided responses through phone conversation about cost breakup of two mass produced parts.

Based on inputs from technical specialists, these responses were further validated to relate the proposed costing guideline. Machining is most critical in these yellow metal casted parts as the process of machining is relatively slower than majority of steel or iron components. Parts are costlier as these are Copper alloys and rejections would cost the manufacturer dearly.

Table: Summary of survey responses – Yellow metal castings

Cost Elements	Cost Breakup (Part 1) (Manufacturer 1)	Contribution (Part 1) (Manufacturer 1)	Cost Breakup (Part 2) (Manufacturer 1)	Contribution (Part 2) (Manufacturer 1)
Raw Material	291	24%	231	20%
Pouring Process	97	8%	93	8%
Fettling	61	5%	58	5%
Machining	558	46%	572	49%
Heat Treatment (If applicable)	0	0%		0%
Finishing	24	2%	29	3%
Overheads and Profit	175	14%	165	14%
Packing and forwarding	7	1%	8	1%
Total	**1213**		**1156**	

(Source: Author's own compilation)
Responses clearly relate to the proposed costing guideline.

6. Conclusion

Casted parts are complex and there are multiple processes that are adopted based on requirements and technical feasibility. Iron & Steel are in majority casted through the very old method of lost wax casting method – Investment castings. Aluminium & Aluminium alloys are casted through die castings – gravity & pressure for mass requirements. Yellow metals (Brass, Bronze, etc) are casted through permanent mould casting process which is similar to gravity die casting method.

Based on the process of manufacturing different types of casted parts the cost of manufacturing and supplies varies and it's important to have a directional tool to help buyers estimate costs beforehand and be prepared for negotiations.

This paper discusses in brief the casting process to extract the various cost elements that lead to the entire costing of casted components/parts. These cost elements are then included in the generic cost structure to propose a costing guideline for reference of buyers to estimate overall cost of investment casted, die casted and yellow metal casted parts. Discussions with experts and study reassures the proposed costing guideline validity.

Business decisions could be made based on costing guidelines at initial stages of product development and design and organisations would benefit from these generic costing guidelines at large. The intent is to provide a simple and powerful tool to estimate cost of engineered casted parts in advance and then adjust final pricing of parts once design and prototypes are approved. In complex business scenarios, that too in manufacturing industry each cost element matters, and a generic costing guideline establishes the best practice to take timely and correct decisions.

This paper has provided an outline for engineered casted parts costing guidelines and further research would establish and re-assure the validity of these costing guidelines and serve as base for developing Cost models.

Additional study and inputs may be added to detail out more types of castings or increase cost elements considered.

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