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A Design to Cost Approach: "Should Costing" in Aerospace

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Abstract: Should costing is a process, whereby one can determine the cost of the part or product, based on the raw materials used, manufacturing costs and overhead production costs. Today the aerospace industry delivers & aligned the targeted customer value messages with the help of buyer-driven process. Aerospace industries regularly produced highly complex products that require long development cycles & face challenges in managing product costs. In this paper we are discussing about the manufacturing part cost can be estimated from dimensional data (i.e. by "Should Costing" Approach) in the part definition rather than based on mass-based parametric models. This method appears to be more accurate than mass-based parametric models or process simulation cost models. This paper also suggests potential follow-on work that could lead to a universal standard for capturing and displaying cost information to the designer.

Keywords: Costing, Parametric, Part, Cost, model etc.

I. INTRODUCTION

1 The driver should be causally related to cost, so that when the designer takes an action that increases cost, the action increases the driver and the driver increases cost. Ideally, this cost driver would be easily deduced from the computer aided design part definition and would provide accurate cost estimation. In the best of all possible worlds, the estimate from this driver would be more accurate than manufacturing engineers' estimates, and therefore superior to manufacturing process simulator cost models. This paper suggests that design information is a cost driver that satisfies all these criteria. Using an receive from the computer aided design workstation instantaneous feedback on the cost impact of every design choice, every feature, every dimension, and every tolerance she enters. The paper also suggests potential follow-on work that could lead to a universal standard for capturing and displaying cost information to the designer.

A plausible reason for the success of the information metric as a predictor of cost is that information is a true link in the causal chain that leads to cost. We will see that, using the information metric:

- The addition of a feature increases the information metric and intuitively increases cost.
- Every facet, chamfer, counter bore, and so on that is added to a feature add dimensions to the definition and thereby increase the information metric. Each requires additional manufacturing operations that should normally increase cost.
- Every tightening of a tolerance increases the information metric and correspondingly increases cost.

II. SIGNIFICANCE OF COSTING

Contemporary computer-aided design tools, such as CATIA, Unigraphics and Pro-Engineer, provide a virtual laboratory in which engineers can experiment with part definitions, leading to optimal design. However, this laboratory is critically flawed by its inability to assess the impact of design on manufacturing cost. Part definitions are represented as three dimensional solid bodies. Computer-aided design tools measure the volume of these bodies, thereby providing instantaneous mass estimates to the engineer. Finite element grids automatically generated within the body (see Figure 1) provide rapid assessment of strength, strain, and heat transfer properties. For parts that perform as aerodynamic flow boundaries, external grids are automatically generated and computational fluid dynamic models provide rapid assessment of flow capacities, drag, or aerodynamic efficiency.

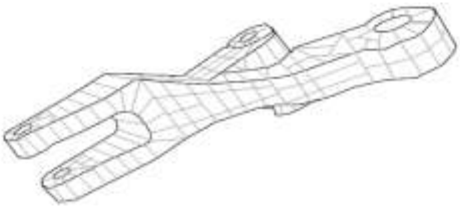

Figure 1: Automated Generated Finite Element Grid

Three dimensional solid models can also be used for animated simulation of assembly operations. The results of all these analyses can be balanced in a formal optimization or in informal tradeoffs that effectively provide optimization. However, no design optimization can succeed without accounting for cost, and a correspondingly rapid analysis of part manufacturing cost is not available. Current costing techniques vary throughout the aerospace industry and include the use of both proprietary and nonproprietary methods. Most companies still retain a traditional cost estimating department that uses experienced individuals who access large proprietary databases.

Cost estimates are generally available only after most tradeoffs are complete. Instead of being optimized in concert with other figures of merit, manufacturing cost is judged by a threshold: acceptable or not acceptable. Manufacturing costs are substantially higher under this approach than they would be if cost were optimized or balanced along with other figures of merit. The work described in this paper is a first step in establishing whether part information correlates well with part cost. If so, a road map needs to be defined that leads us to a point where cost modules become standard features on all commercially available CAD systems.

III. STATE OF PART COSTING

Today's part cost estimating tools fall into two categories: manufacturing process planning tools and parametric cost estimators. Manufacturing process planning tools generally require the design engineer to determine how each feature on the part will be machined and then, using parameters of the feature, estimate the cost of each manufacturing operation. In essence, they automate the analysis performed by manufacturing engineers when they plan the manufacturing processes for a part. The best of these models can quite accurately reproduce the cost estimates of manufacturing engineers. Today's state of the art, however, requires that the designer translate the design drawing into a parametric description of the part, requiring dozens to hundreds of parameters. The models cannot cope with new design processes. They are calibrated to the processes existing at the time the model was released. Also, manufacturing engineering cost estimates are generally far less accurate than estimates of other figures of merit, such as mass, flow, drag, or efficiency. Parametric cost models statistically estimate part cost based on the correlation between historical cost data and part properties that are deemed to be cost drivers, such as mass and material. A positive statistical correlation between two properties, such as mass and cost, may exist because the first causes the second. Or the correlation may exist because the second property causes the first (see Figure 2). Or there may be some third factor that causes both mass and cost. In any case, a correlation is a valid basis for prediction. It is not, however, a sufficient argument for causation.

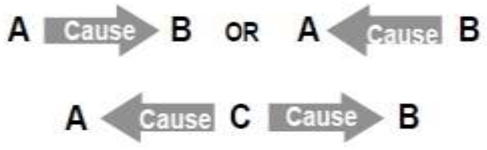

Figure 2: Correlation and causation

Price-H is an example of a popular aerospace cost model that uses mass as the primary cost driver and adjusts cost for material type. Mass is the only readily available measure of a wide variety of aerospace parts, so it is generally the principal cost driver by default. However, it is doubtful that mass actually *causes* cost to a major extent. Causation is unimportant when the model is used simply to predict cost. It is, however, a critical concern when engineers use the model to optimize part designs. The model will induce the engineer to reduce mass in order to reduce cost. Aerospace designers should immediately see the fallacy here: we normally incur higher manufacturing cost as we reduce mass by strategies such as more precise machining.

In design space excursions in the vicinity of an optimum design, reduced mass typically corresponds to higher cost, not lower cost. Thus, engineers who "drive" cost by turning the mass knob on a cost model are liable to bear off in a very wrong direction. Another serious deficiency of mass as a primary cost driver in engineering design is that, in most systems or products, mass is already a key figure of merit on which parts are assessed. When cost is predicted from mass, and cost and mass are input to an optimization algorithm, the effect is as if mass were counted twice and cost were ignored.

IV. COST MODEL & PROCEDURE

According to Hoult and Muter demonstrate that for a particular machining process, the time to process a part (and, by1 a discrete noiseless channel inference, the cost) is proportional to the information content of the process definition on the part drawing. The method that Hoult and Muter used for measuring information is:

$$I = \sum_{k=1}^{N} Log_2\left(\frac{dimension_k}{tolerance_k}\right)$$

where, N is the number of dimensions that describe the process.

This means that, for every dimension used to describe the process, the dimension is divided by its respective tolerance. The result is a normalized dimension where the tolerance is the base. The logarithm determines the number of bits required to represent the normalized dimension. The summation yields the log of the product of all the normalized dimensions or, alternatively, the total number of bits necessary to describe all the normalized dimensions needed to define the process. This relates to information theory and to entropy as follows. The macroscopic definition of the process is the process definition with all dimensions located but not stated. For each dimension, the tolerance is known and the dimension is expressed as a multiple of the tolerance. The microscopic definition includes the actual values of the tolerances. The entropy, I, is the logarithm of all the possible combinations of dimensions that could be in the definition. Information theory also views the definition, without the explicit dimensions, as a communications channel. The explicit values of the dimensions (normalized to their respective tolerances) combine to form a message. The information metric is the length of the message in bits which is also equal to I.

We first separated parts into thirty part types. In the course of the study we learned that for some of these part types, such as electrical equipment, sensors and pumps, this method does not directly apply because the part drawing only describes the shape of the part. A specification is used to actually define the part. The exterior drawing has little to do with the part cost. (From the outside, an engine control and a voltage regulator may be very similar). Thus, we ended with the twenty-two part types listed in Table 1.

Table 1: Calculation Table for Design Information

Dimensions	Tolerances	Count	Bit String
0.5	0.01	2	5.65
0.75	0.01		1
0.25	0.01	4	6.23
0.1	0.01	4	4.64
0.05	0.01	4	5.32
7.825	0.05		4.32
0.5	0.01	2	7.29
0.35	0.01		6.65
Quantity of information			41.01

For each part type we attempted to identify ten to twenty parts (part numbers) that were distinctly different and for which we had a drawing and a current actual manufacturing cost. For some types we were not able to find ten such parts. For others, parts were abundant and we included more than twenty. On average, we examined thirteen parts within each type.

For each part, we quantified the information on the drawing.

1. All dimensions were quantified according to equation (a). For dimensions without tolerances, such as reference dimensions, the drawing's default tolerance was used. (We debated whether to include reference dimensions, as they are not true dimensions. However, in many cases they were used in such a way as to direct processing operations, so that they caused cost like normal dimensions. Therefore we counted them).
2. Indications of repetitions (such as "in 4 places") were counted as dimensions with a tolerance of one. That is, the bit string length of the count was used.
3. Numbers in textual notes were counted if they included a tolerance ("Heat treat for 4 hours plus or minus 30 minutes") or if they were obviously an integer, in which case a tolerance of one was used.
4. For drawings that included assembly instructions, one bit was added for every part number listed for assembly.

V. DATA ANALYSIS

Due to the limited scope of this study, this algorithm was never tested against alternative approaches to measuring information, even as simple as different weightings of the measures listed above. It is very probable that there is an alternative assessment method that would provide better correlation and more accurate prediction of cost.

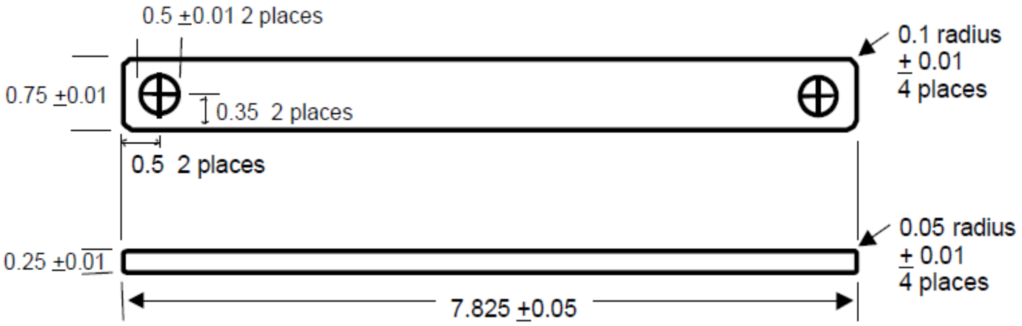

Figure 3: Part Definition Example

All the dimensions, tolerances, and so on, were entered into Excel spreadsheets, one sheet per part number, and the spreadsheets were stored in an Access database. Most drawings had a few hundred dimensions. Some had as many as one thousand. To make this method more clear, an example is provided for a very simple part (Figure 3).

There are eight dimensions on the drawing. Consider first the diameter of the round hole, which is 0.5". The tolerance is 0.01". The ratio of dimension to tolerance is 0.5 / 0.01 = 50. Thus, the dimension is 50, normalized to its tolerance. The base 2 logarithm of 50 is 5.65. That is, it takes 6 bits to represent the number 50 in binary, but the first bit is not really fully used. Encoded in a long string with other data, the number would only require 5.65 bits. This is summarized in the first line of Table 1.This dimension applies to two places in the drawing (both of the holes). Two, being a count, does not need normalization. The bit string length associated with two is one (the base 2 logarithm of two). This is reflected in the second line of Table 1. Later lines combine the dimension and count into a single bit string length for convenience. When all the dimensions and counts have been assessed, the bit string lengths are totaled in the right hand column to about 41, which is the quantity of design information in the drawing.

VI. INTERPRETATION & WEAKNESS OF COST DATA

1. As mentioned previously, the algorithm chosen for quantifying design information was a first guess, and it is reasonable to expect that it could be significantly improved with further research.
2. The part type distinctions were made prior to gathering the data. It seems likely that the data may suggest better groupings. For example, shafts and gears cluster around the same regression line and could be treated as a single group. (Notice however that some groups were effectively split, usually by material, after analyzing the data. For example, disks were divided into titanium disks and other disks).
3. The blisks group and perhaps the tip tracks were too small to make the correlation data meaningful. In fact, none of the groups with less than twenty parts are very compelling.
4. There was no attempt to evaluate any aspect of the design definition other than numbers that appear on the drawing. A more advanced approach might be able to use more data in its evaluation.
5. Almost all the regression fits are linear. With more data there would be opportunity to consider some second order fits that may improve accuracy. Note though that Hoult and Muter proposed an underlying theory that claims that fits should be linear.

VII. CONCLUSION

It is concluded from the analysis of part costing that the quantity of information that must be communicated from design to manufacturing in order to correctly make the part. Therefore, design environments that wish to provide the designer with manufacturing cost implications of his or her design decisions should measure the information content of the design as the basis of manufacturing cost estimates. This can be done simply on modern computer aided design workstations. Resulting estimates are superior to mass-based. parametric cost models and even superior to process based estimates traditionally performed manually by manufacturing engineers. Because information-based estimates need take no separate account of the manufacturing processes that will be used, mature manufacturing costs can be estimated for radical new parts and composite materials.

VIII. REFERENCES

[1]. Aviation Week & Space Technology, McGraw-Hill, New York. January 8, 1996.

[2]. Hoult, David P. and Muter Stuart W. “Cost Comparisons of Alternative Designs: An Information Based Method”, The Manufacturing Institute at the Massachusetts Institute of Technology, 1993.

[3]. Shannon, Claude E. The Mathematical Theory of Communication, University of Illinois Press, Urbana, IL, 1963.

[4]. US Bureau of Mines, Mineral Yearbook, United States Government Printing Office, Washington, DC.1990.

[5]. Abels, Eileen G, “Improving Reference Service Cost Studies”, Library & Information Science Research, 19 (1997): 135-152.

[6]. Abels, Eileen G., Kantor, Paul B., and Saracevic, Tefko, “Studying the Cost and Value of Library and Information Services: Applying Functional Cost Analysis.” Journal of the American Society for Information Science 47 (1996): 217-227.