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Value Engineering Additives In Optical Sighting Devices

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Abstract

This paper discusses some of the Value Engineering approaches that were employed in the design and fabrication of optical sighting devices designed to be used in tracked vehicles subjected to conditions of severe shock and vibration as well as wide variations in temperature. Various avenues of approach are examined as they relate to the achievement of design to unit production cost (DTUPC) goals for medium volume production programs.

Introduction

The question might be raised - What place does a topic like Value Engineering have at a conference of optical engineers? After having been involved with the M1, Bradley and DIVAD sighting device programs, I believe that Value Engineering is a key ingredient. Value Engineering should begin during the conceptual phases of a project and be "on going" throughout the program.

Initial Conceptual Ideas

Once conceptual ideas are established and the project at hand is doled out to the various design disciplines and their staffs, it becomes increasingly difficult and costly to retract ideas and establish new ones. Designs should be kept soft and flexible - sketches normally suffice. With this mode of operation, ideas can be formulated, investigated, simplified, combined and discarded without wasting precious time-consuming board time. When designs become too rigid too soon, flexibility and creativity suffer. A degree of dissatisfaction with any design may be a necessary ingredient to Value Engineering.

Collaboration with the Customer

Collaboration with the customer, while not always easily achieved under some of the bidding procedures of government related work, normally brings affirmative results. The accurate definition of space claims, trading dollars for performance (specifications), human factors, mechanical, electrical, microwave and optical interfacing considerations are important topics for discussion with the customer.

Simplicity of Design

Normally the mechanical engineer engaged in electro-optical work is the packaging engineer for the microwave engineer, the electrical engineer as well as the optical engineer. Consequently, familiarity with these disciplines and the ability to discuss topics freely are important to the success of any program. Underlying the thought process should be a theme of simplicity - it is the essence of good design and good design results in value -

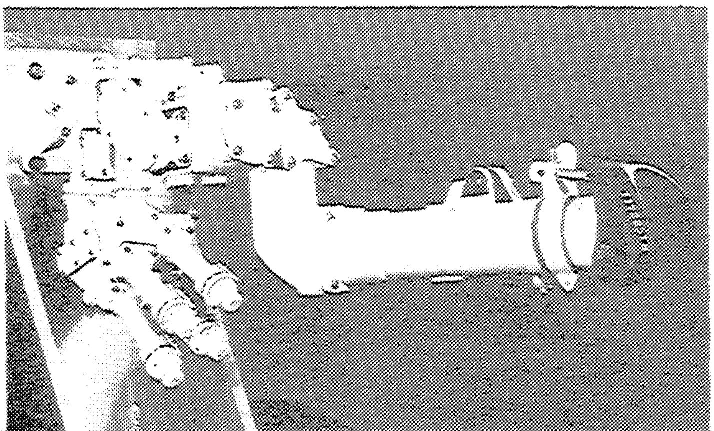

Fig. 1

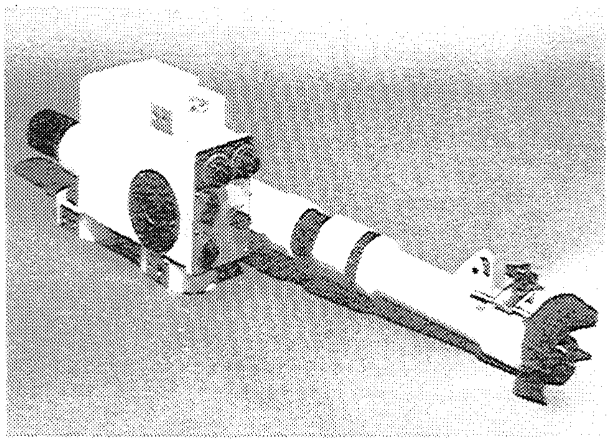

Fig. 2

value to the manufacturer by way of ease of fabrication thru individual part manufacture and assembly, to the customer by way of ease of maintainability and use, and ultimately, if government work, to you as a taxpayer because of lower cost. Figures 1&2 illustrate the importance of Value Engineering at the initial concept level of design. The pictured sights were designed to achieve the same end user function. It doesn't require a great deal of imagination to realize which instrument was less costly to produce from the number, complexity and maintainability of the parts involved. In depth examination of the specifications and the space claims were critical to the final design of the instrument shown in Figure 2.

Geometric Tolerancing

Value Engineering can be very subtle as well as spectacular - one subtle but beneficial program is to employ geometric dimensioning and tolerancing. Benefits include (1) additional tolerance over the more conventional coordinate system, (2) relating dimensions to function, (3) visibility as to interchangeability of interfacing parts, (4) ease of building functional gaging, (5) targeting of work for repetitive machine tool operations and (6) providing a wide latitude in the selection of cutting tools.

Figure 3 illustrates the normal coordinate technique of dimensioning a hole from the edge of a part. The coordinate system defines a discrete square area .010" x .010" but when we analyze this area we can question why the area within the square is any more sacred than a circumscribed circle about the square. In Figure 4 we consider the area included in the circumscribed circle as opposed to the square and we find that our tolerance zone is increased by 57%. The geometric tolerancing for our feature can be defined per notation in Figure 5 which demonstrates the concept of zero tolerance at maximum material condition (MMC). This concept allows the acceptance of parts over the widest possible tolerance range and at the same time allows high visibility with regard to gage construction.

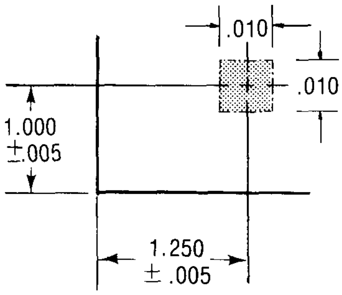

Fig. 3

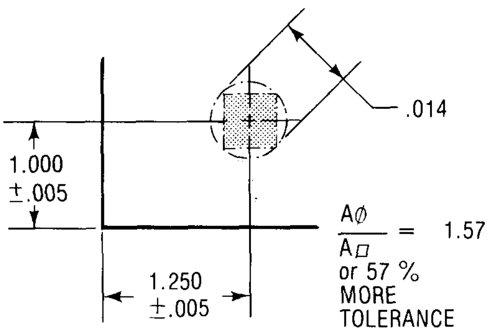

Fig. 4

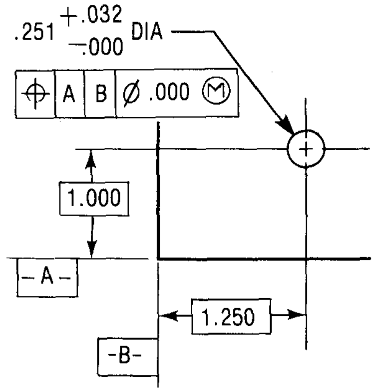

Fig. 5

It is not the intent of the writer to explore all of the ramifications of geometric tolerancing; rather to indicate that this technique of dimensioning is an important Value Engineering tool. The reader should reference[1] Dimensioning and Tolerancing ANSI Y14.5-1973 published by The American Society of Mechanical Engineers for information regarding the implementation of this important engineering tool.

Net Shape-Function

The ability to achieve a net shape-function with regard to mechanical parts is an interesting subject for consideration when discussing Value Engineering. It may be one of the most dynamic as both materials and methods for fabrication are constantly changing. The more exposure the design engineer has to materials and processes the more articulate will be his work. Underlying the whole area of study is the subject of DTUPC (Design To Unit Production Cost) which is related to quantity of buy. For this reason the designer must have access to information regarding total buy, rate of requirement and the available tooling budget.

Fabrication Techniques

Because of the broad scope of fabrication techniques, it is impossible to discuss them at length at this time but perhaps a list, if only partial, may be helpful in choosing one(s) to satisfy DTUPC figures.

Machine from Solid
Shape & Weld
Forge
Sand Cast
Shell Cast
Permanent Mold Cast

Investment Cast (Lost Wax)
Die Cast
Extrude
Powder Metallurgy
Stamp-blank/bend/spin/draw
Fine-Line Blank

Electroform
Plate/Coat/Paint/
Polish/Tumble/
Grit Blast/Etch
Chemically Machine
Replicate

Machine:

Saw	Turn	Thread
Mill	Drill	Tap
Ream	Burnish	Broach
Grind	Knurl	EDM

Weld - Laser/Electron Beam/Arc-electric/Gas/Friction

Adhesive Bond

Replicated/Micro-Machined Folding Optics

Certainly replicated/micro-machined folding optics have importance when discussing Value Engineering. Advantages of folding optics made by these techniques are the resistance of the optic element to shock and vibration and thermal stresses since the optical surface is virtually an integral part of the mechanical element. Furthermore, the opto-mechanical element may have other functions such as a seal, a pivotal axis or a mechanical mount.

In the case of micro-machined optics it is possible to maintain an extremely high degree of accuracy between the optical surface and the mechanical interface when the latter is used as a machining datum for producing the micro-machined surface. Such is the case with the mirror which is pictured in Figure 6. In this instance, the closely toleranced centerless ground shaft is used as one of the machining datums for the micro-machined mirror facet. When the mirror is used as a scanner and the shaft is fitted into high class bearings, the tracking error becomes very small.

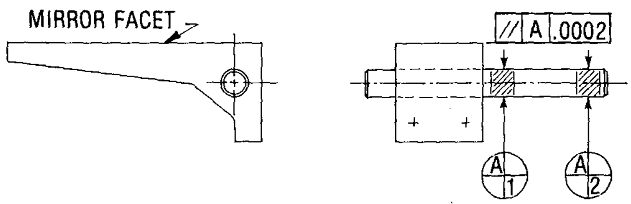

Fig. 6

Examples of other replicated/micro-machined mirrors which integrate mounting and sealing are depicted in Figures 7 and 8.

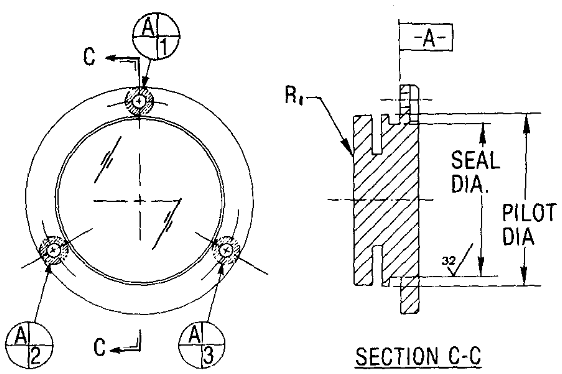

Fig. 7

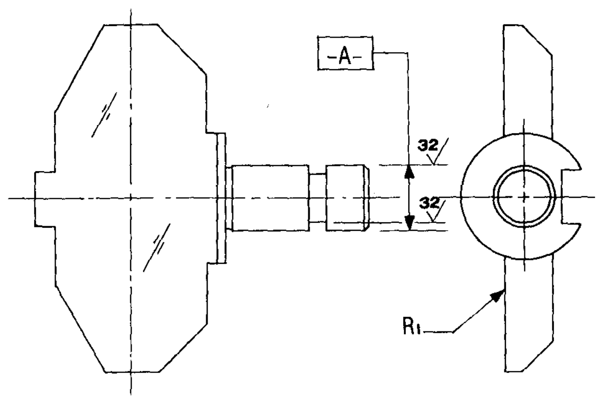

Fig. 8

Plastics in Instrumentation

This discussion will not deal with plastics as used in the manufacture of optical elements; rather it will deal with peripheral plastic components used in instrumentation. The wide range of properties which are available to the designer who uses plastic components is extensive depending upon the formulation of the base resin and fillers. Manufacturers of plastic components, mold designers and suppliers of resins may all be helpful in choosing the most suitable material for a particular application. In any event, molding of plastic components usually results in net finished shapes. A beneficial feature of the molding process is the ability to neatly part mark components which is often required in government related work. In many cases it costs more to part mark components after fabrication than it does to manufacture them.

It was once thought that plastic molders would only consider very high quantity production lots but there are molders who make it their business to build 'soft' tooling and will accept small quantity order lots. In fact, some houses specialize in prototype work where parts are molded for testing purposes prior to the construction of 'hard' tooling.

A look at some plastic parts by function may be a good way to approach this subject further. One application found to be viable was the use of molded plastic lens spacers noted in Figures 9 and 10. The spacers were textured on their inside diameters to reduce light

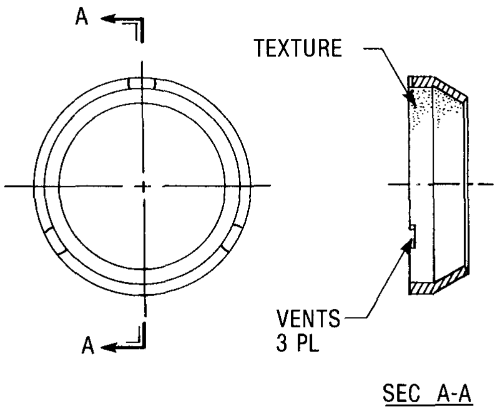

Fig. 9

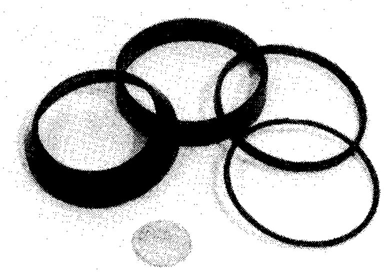

Fig. 10

reflectance while the ejection pins were set high in the mold cavities so that the dry nitrogen which was used to purge the instrumentation could enter the spaces between the lenses. Although there were problems in maintaining the roundness of the 'as molded' parts this presented no problem when the spacers were installed in the bores of the lens housings. Another advantage of the plastic lens spacers was that they were softer than the glass and thus did not chafe and score the lenses in vibration environments. This is in opposition to situations which the writer has observed where anodized aluminum spacers severely abraided the lenses with the result that the interior spaces of the lens cells were contaminated with ground glass.

The use of die cut spacers fabricated from polyester sheet stock has proven to be a viable and inexpensive technique for separating air spaced doublets. Figure 11 illustrates such a spacer where an outer ring of material supports three equally spaced tabs which act as spacing elements for the doublet lenses. The tabs allow the nitrogen to bleed into the space between the doublets and at the same time provide a stable seat for the optics.

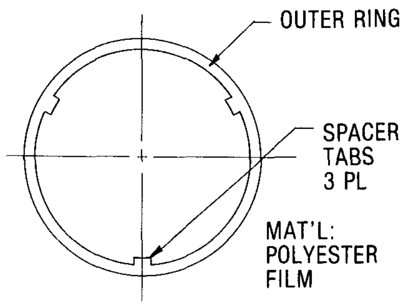

Fig. 11

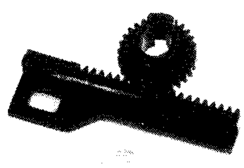

Fig. 12

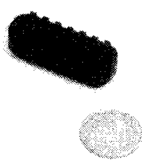

Fig. 13

Plastic components may be used for mechanical drive elements - typical components shown are the rack and mating gear (Figure 12) and a multistart segmental nut (Figure 13). The latter component was priced at $20 in a copper based alloy whereas the cost of the plastic component was $.25. The aforementioned drive components were made from acetal resins which were self lubricating and thus eliminated the need for viscous lubricants which could have contaminated adjacent optical elements. Additional uses of plastic components are illustrated by the graduated paint filled dial (Figure 14) and the filter mechanism (Figure 15).

Note: The pictured coins are U.S. pennies

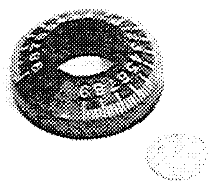

Fig. 14

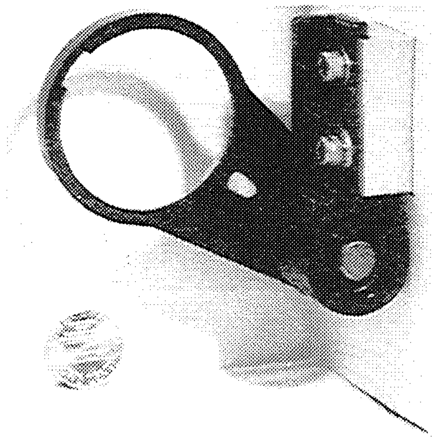

Fig. 15

Fineline Blankings

You will note that in the list of methods of manufacture that stamping is separated from fineline blanking even though the two methods of manufacture have similar overtones. However, fineline blankings are greatly superior to stampings as far as edge definition and finish are concerned and so deserve to be specially categorized. It was for these reasons that fineline blankings were able to be used in a specialized cam application.

Initially the cams were manufactured from two grades of 400 series stainless steel - the shank portion was made from 410 stainless while the cam surfaces were made from 440 stainless which was hardened to a R_C of about 40 (Figure 16). The two piece construction was

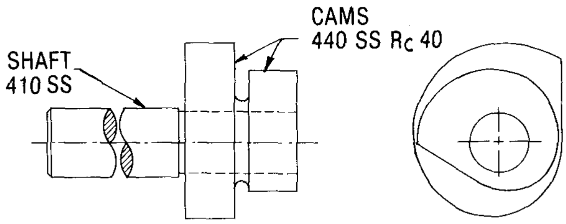

Fig. 16

brazed together and then the shank and cam profiles were generated by grinding with a resultant cost of over $40 from an outside vendor. Coupled with this cost was a delivery problem due to conflicting priorities with other government programs and a limited number of suppliers capable of producing the ground cams.

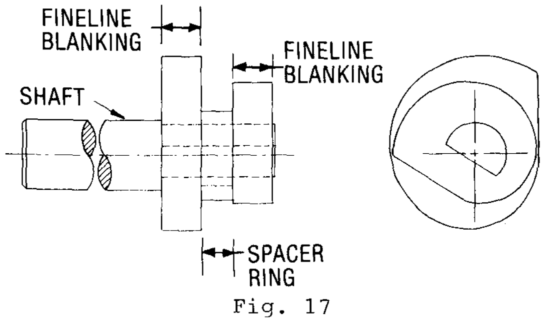

Fig. 17

Fig. 18

Presently the cams are made from a multi-piece construction - a stock 300 series stainless steel centerless ground shank is knurled and ground to form an orienting key and seat for two case hardened fineline blankings which are separated by a tubular spacer (Figure 16). The blankings and spacer are pressed and bonded to the shank in a simple pressing fixture. Of further note is the fact that the instrumentation required right and left hand versions of cams having the same kinematic characteristics. By turning the cam blanks 180 degrees to the shank it was possible to make both versions using the same blankings (Figure 18). It is interesting to note that the piece price for each of the blankings is about $.65 and the shanks and spacers are readily available screw machine parts. Thus it is possible to make the required cams without the gating process of profile grinding at a fraction of the cost of the former construction.

Powder Metallurgy

The powder metallurgy process can produce parts to close dimensions so that net shapes may be achieved. Other advantages of this process include the capability of controlling density, using mixtures of materials (which may aid in secondary machining operations) and impregnating parts with lubricants - all important considerations for the Value Engineer.

A tightly toleranced dovetail link used to drive the replicated mirror shown in Figure 8 is shown in Figure 19. In the prototype stage, this part was fabricated from wrought stock at a cost of about $45. In the early production stages, the part was fabricated from an investment casting which had to be qualified by machining to bring it to final size; the cost of the investment casting, less machining, was about $3. Presently this part is made by a powder metallurgy firm as a finished product for $.153. This part illustrates the importance of making Value Engineering an 'on-going' program. Often, because of program scheduling, it is impossible to explore, test and evaluate the most advantageous method of manufacturing a piece of hardware. This link is a good example of an earlier comment stating that dissatisfaction may be a necessary ingredient to Value Engineering.

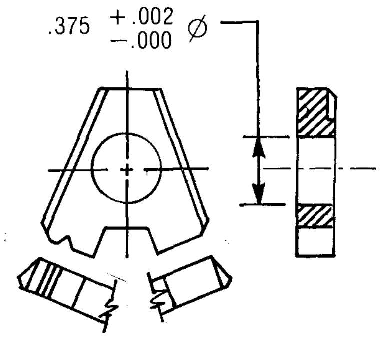

Fig. 19

Plating

Enhancement of surfaces by plating techniques has interesting overtones. An example is the hard coated journal and diameter which is plated onto the aluminum elbow housing shown in Figure 20. This elbow housing fits into another aluminum housing cast from the same alloy and so thermally these parts expand and contract at the same rate thus maintaining the same amount of journal clearance over the entire temperature range of -70F to +170F. The female housing was anodized by conventional means which was a required surface treatment of the part by contract specification. The male member, because of ease of masking in the plating process, was chosen as the member to be hard coated. Exhaustive cyclical testing proved the design to be sound with the result that intermediate journal materials were not required to satisfy the contract life cycle tests. This sort of thing has far reaching effects - not only are drawings elminated but the sparing problem and associated jigs and fixtures are eliminated as are the concerns about corrosion because of dissimilar metals being in contact with one another.

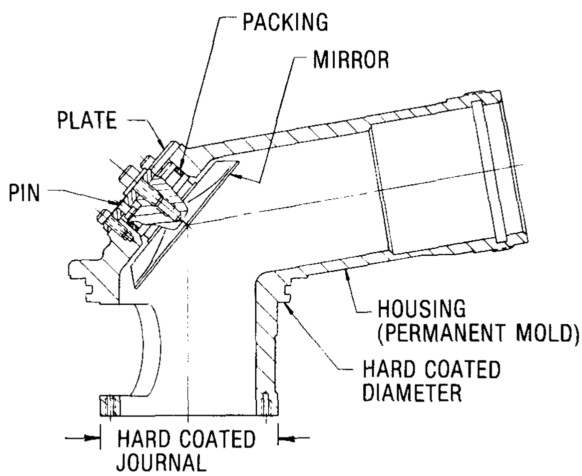

Fig. 20

Conclusion

It has been the intent of this paper to demonstrate that Value Engineering is not a science but rather a philosophy which should be adopted by all disciplines within organizations. In order for the philosophy to work there must be communication between all persons who ultimately produce or use the product in question.... the results of such a program will be rewarding to all.

Reference

1. "Dimensioning and Tolerancing ANSI Y14.5-1973" - Published by The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York, N.Y. 10017