Optical Design Compensation from Engineering to Production Manufacturing

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Abstract: This paper will discuss transitioning a precision optical system from engineering to a manufacturing process stream.

OCIS codes: (220.3620) Lens design; (220.3630) Lenses; (220.4610) Optical fabrication

1. Introduction

Many optical systems for precision applications such as optical inspection, micro-lithography, DVD mastering, and projection printing require significant optical engineering involvement to support the manufacturing team in fabricating these systems. Performance demands placed upon lenses used in these industries often dictate diffraction limited wavefront quality, minimal image distortion, and resolution of very small features. Achieving the necessary "as-built" performance requirements for the lens assembly can mean optical designer involvement to select and compensate manufactured parts, prior to release to the component assembly team. This level of detailed engineering involvement is suitable for proto-type quantities but can constrain the manufacturing stream when the system transitions to sizeable production quantities. Support in the manufacture of volume assemblies can require a dedicated team of optical design engineers to manage the day to day project needs of lens selection and compensation in order to keep pace with the program's delivery rate. A second option to manage the engineering duties of precision optical systems is to develop a manufacturing stream which enables transferring and transitioning designer project support to the assembly and fabrication teams.

2. Manufacturing Philosophy and Key Components

In producing many state of the art optical systems, the manufacturing strategy hinges around a philosophy whereby each fabricated objective is first modeled and simulated in optical design software prior to committing to assembling the components (figure 1). A group of lens elements will first be custom selected from the population of manufactured parts to minimize aberration build up. The component's measured fabrication properties (radius, thickness, index,…) will be modeled in design code and further performance gains achieved by optimizing with pre-determined air spaces.

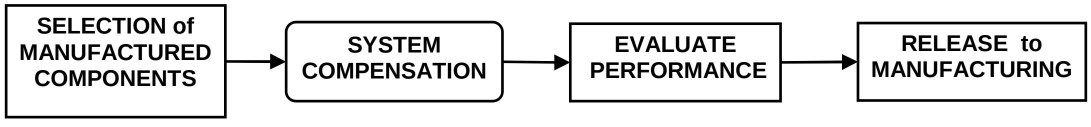

Fig. 1 Manufacturing Philosophy

International Optical Design Conference 2006, edited by G. Groot Gregory,
Joseph M. Howard, R. John Koshel, SPIE Vol. 6342, 63422S,

Mechanical parts will be adjusted accordingly to achieve desired lens spacings. This manufacturing concept allows for looser optical fabrication tolerances as opposed to building a static objective. Fine tuning and computer simulation of each optical assembly has often been the task of the optical designer. This methodology is fine for small quantity production, but how might it be applied to producing optical systems with sizeable volume?

A manufacturing strategy has been developed to create a Volume Manufacturing Compensation Platform (VMCP) for quantity production of high performance optical systems. A suitable software platform and suite of compensation tools has been implemented to integrate optical design support duties to a volume manufacturing stream (VMS). The key components of the platform (figure 2) consist of an integrated computer network accessible to design and manufacturing, electronic fabrication records stored in a Lens Manufacturing Database (LMD)[1], optical design analysis/compensation software, and lens assembly report specific to each manufactured lens unit. This infrastructure lends itself to automating the design compensation process, which allows for incorporation into a production VMS.

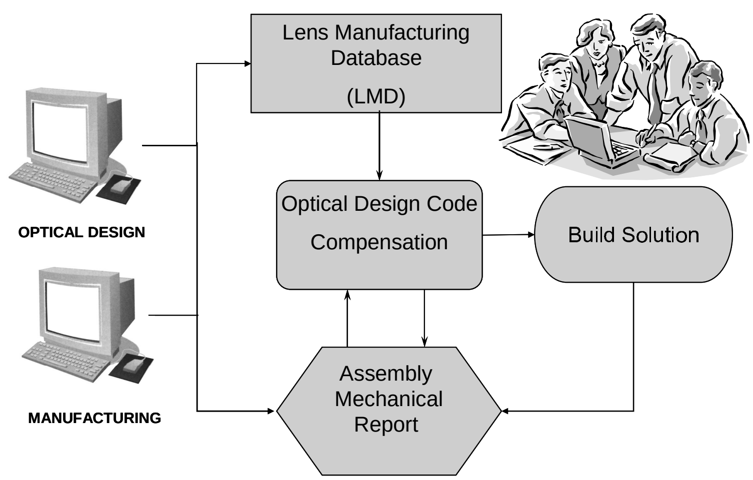

Fig. 2. Volume Manufacturing Compensation Platform

3. Project Requirements for VMCP

There are basic requirements the project must fulfill to be integrated into the VMCP. The volume must be large enough to justify spending time and effort to develop the underlying software code to manage the data collection, design optimization, solution tracking, and reporting. In many optical projects if more than one to two dozen lenses are to be manufactured, the investment effort will be re-couped.

The design compensation strategy must be robust, well understood, and characterized. This means the system compensation algorithm does not need to be fine tuned or adjusted on a set by set basis to yield an acceptable solution. The tolerance budgets need to be carefully assigned to different manufacturing parameters such as optics, mechanics, assembly, and test. This aids in establishing acceptance threshold criteria to judge if a lens solution can be released to assembly for building.

4. VMCP and Operation

The VMCP is developed to be compatible with a variety of different lens systems, complexities, compensation paths, and manufacturing requirements. Each lens system has its own unique built in performance metrics and compensation processes which need to be adhered to. These parameters are decided jointly between the lens design and manufacturing teams. Necessary process information is committed to work procedures and flow diagrams. An optical designer generally oversees the project's development and integration into the VMCP. The design quality metrics computed in the software consist of parameters utilized to judge adherence to design tolerances, specification, and any merits which may be quantified in the test laboratory. For example, theoretical performance merits evaluated could include wavefront RMS and spherical aberration, which could then be verified by interferometry in the test lab.

Running design compensations with the VMCP is relatively simple. The optical elements to be assembled are selected from the Lens Manufacturing Database. An implemented LMD facilitates this process by a simple point and click user interface (figure 3). Components are grouped by their project designated set number or available stock elements. Each lens component is compared to manufacturing specifications and the impact to performance computed. This information is utilized to quickly determine the performance change due to a particular component being placed into a lens assembly. The lens set's specific manufactured data (radius, ct, index,…) can easily be exported to optical design code for optimization and analysis.

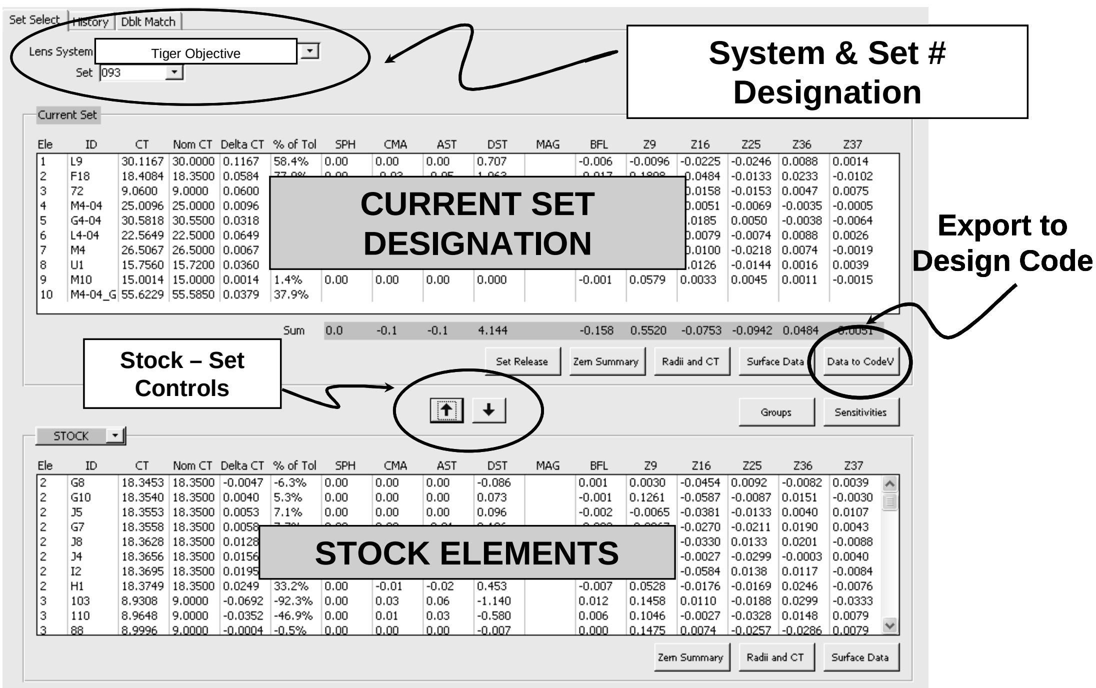

Fig. 3. Project Element Selection Interface in LMD

Additional set unique mechanical and as-built air space data, stored in the assembly mechanical report, can be exported, combined with the element LMD information and compensated with the VMCP. At the end of the lens compensation phase, performance merits are evaluated against the threshold criteria. If acceptable performance is achieved, the manufacturing solution is reported and released to assembly (figure 4).

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SYSTEM HAS PASSED ALL PERFORMANCE CRITERIA
APPROVED FOR RELEASE TO MANUFACTURING
LENS NAME: TIGER
SET NUMBER: 204

16-May-2006

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DATE	SET	PARAM	VALUE	LOWER	UPPER	P/F
16-May-2006	204	RMS POLY	0.0630	0.0200	0.0850	pass
16-May-2006	204	MAG	-2.9168	-2.9197	-2.9139	pass
16-May-2006	204	DIST	5.5711	0.0000	10.0000	pass
16-May-2006	204	DIST C	5.3875	0.0000	10.0000	pass
16-May-2006	204	DOF	52.4630	44.0000	60.0000	pass
16-May-2006	204	CURV	9.3870	4.5000	12.7000	pass
16-May-2006	204	ASTIG	10.1010	7.0000	15.0000	pass
16-May-2006	204	MTF MIN	0.7970	0.7400	0.8500	pass
16-May-2006	204	TT	822.9996	822.0000	824.0000	pass
16-May-2006	204	V-V OBJ	624.7564	624.3000	625.3000	pass
16-May-2006	204	V-IMG	738.0056	737.5000	738.5000	pass
16-May-2006	204	TEL OBJ	2.6182	0.0000	5.0000	pass
16-May-2006	204	TEL IMG	5.6940	0.0000	10.0000	pass
16-May-2006	204	MERIT	0.1434	0.1245	0.1650	pass

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AIR SPACE REPORT
16-May-2006
TIGER
SET 204

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SPACE	VALUE
2-3	26.3393
1r2-3r1	295.0679
3-4/5	29.2131
cem	0.0332
4/5-6	0.6479
6-Stop	26.4398
6-7	119.5048

Fig. 4. Objective performance and solution report

Should the design fail to achieve acceptable performance, the solution is not released to manufacturing and the user is recommended to alter the mix of selected elements and re-run the compensation.

The VMCP includes history information. Each time a lens system is run on the platform, performance and compensation data is archived. Historical project data can be reviewed for manufacturing performance trends, adherence to specification, and statistics.

5. Design Transition to Volume Production

The VMCP architecture permits easy transition of lens system support from proto-type to volume production. This platform offers several advantages to the manufacturing community. Manufacturing personnel can take over many of the routine project support design duties that have traditionally been performed by an optical designer. This alleviates dependence by manufacturing upon the engineering staff for day to day project support. The cycle time for design compensation is greatly reduced as the process is automated. Each system within a project is uniformly compensated with the same tools, variables, and methodology. Multiple users can easily be trained to run the VMCP allowing for additional staff versatility within programs. Each individual project maintains it own custom compensation strategy and unique set of performance merits. The threshold criteria dictate to the user if it's acceptable to build a particular lens set. This eliminates many of the subjective performance decisions that have routinely been made by an optical designer. Any modifications and changes in compensation philosophy would need to be reviewed by an optical designer before implementation into the VMCP.

6. Summary

A manufacturing compensation and analysis stream has been developed to assist with the manufacturing support duties of production optical systems. This concept can be utilized to transition/transfer optical designer engineering system support activities directly to manufacturing personnel. This can include selection of system parts to be assembled, analysis, and compensation of these parts prior to committing to building. Manufactured lens data and mechanical assembly measurements can be built into design models to predict what level of performance may be achieved by a given assembly. If performance is acceptable, the parts can be released for assembly. This streamline process circumvents engineering involvement in production activities and allows for manufacturing to transition designs from proto-type to volume.

References

1. Tienvieri, C., et al, “Modern lens design using a lens manufacturing database”, SPIE Proceedings, IODC 1998, vol 3482, pp. 508-518.