OPTICAL MEASUREMENT DEVICES SUPPORTING P&D ON DIGITAL TRANSFORMATION

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ABSTRACT

In the particular environment of the automotive product development area, where the acronym "VUCA" (Volatile / Uncertain / Complex / Ambiguous) shows the current reality, optical measurement devices are key tools for assertiveness in decision making. The usage of these tools in the development and analysis of components of Diesel injection or support systems showed versatility and great possibilities, from the verification of dimensional specificity, wear verification, analysis of additively manufactured parts, verification of initial supply at scale, surface characterization, and specification conformity. A new form of development appeared, however, less ambiguous, uncertain, and volatile with a reduction in response times and a new way of having and seeing the results of the analyzes for decision making. The benefits, above mentioned, were obtained in the development of a new starting system for diesel engines, control valve for motors of power up to 19kW, as well as systems of injectors and pumps already consolidated.

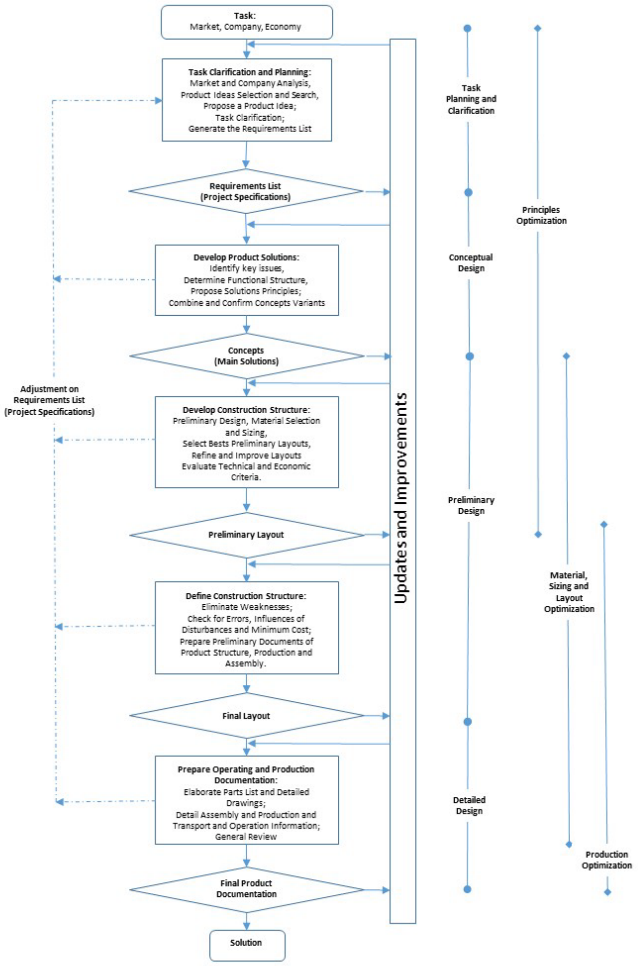
INTRODUCTION

Working in automotive product development engineering, where there is the materialization of the acronym "VUCA", forces the companies to shorten the product cycles and to innovate in new fields and market, as explained by Burchrdat & Maisch [1] in their study of agile approach for smart products and services. In this context, the optical measuring equipment shows great value.

First, in order to understand the *Complexity* of the product development reality and its stages, processes, and unfolding, the flow of product development presented by Paul & Beitz [2] assists us in this, as seen in Picture 1.

As can be seen in Picture 1, product design flow is divided into four main phases:

• Task Clarification;
• Conceptual Design;
• Preliminary Design;
• Detailed Design.



Picture 1 –Product development flow according to Paul & Beitz [2].

In task clarification, the main activity is the setting of the project requirements, in which the requirements of the clients are studied, to establish the initial information of the project. This stage consists of clarifying and formulating the task, to generate the design requirements. Another objective of this step is to analyze the feasibility of the product. At this stage, the information is very *Volatile* and the *Uncertainties* are generally greater than the certainties.

Heimicke et al [3] presented that a popular method to deal with the resulting uncertainty in the entire development phases which is to combine agile process planning, for flexibility, with structuring product development elements, for avoiding multiple replanning. This approach was named as ASD – Agile Systems Design.

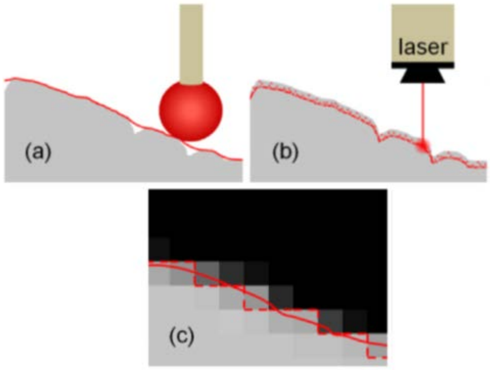
The conceptual design phase consists in the identification of the essential problems, the establishment of the structure of functions, search and combination of the principle of a solution, and attainment of different principles of conception for a resulting design of the product. At this time of the project, the biggest challenge is to unite all the parts and reduce the *Ambiguity* of the requirements developed previously for the materialization of a solution in the form of a product or service.

As an constant requirement for Agile system, the interaction between product design, production planning, operations and their sub-disciplines are necessary. Schindler & Verl [4] presented an innovative method based on the 3D digitalization for an existing production systems in order to abandons a strictly sequential project approach, relying on an agile process instead. This 3D digitalization approach can be transferred to the product development mindset as well.

Nowadays, as a product measurement equipment, the Coordinate Measuring Machine (CMM) and the Stylus instrument are the most common type of measurement technology used in the industry. They are equipped with a probe or a stylus physically in contact with the surface under measurement, the CMM is used for discrete 3D coordinate point's measurement and the Stylus instrument for surface roughness characterization. According to Quagliotti [5], the contact instruments have three main drawbacks: due to the probe size they do not completely penetrate the valleys of the surface, the force applied by the probe can deform plastically the polished surfaces and the acquisition may require a long measuring time.

The optical measurement instruments overcome these drawbacks from the more traditional contact measurement, performing a non-contact measurement of both continuous 3D coordinate measurement and surface roughness characterization. Furthermore, they have a high vertical resolution, can acquire large areas in a faster time, and do not damage the surface inspected. According to Quagliotti [5], the optical instruments are divided into scanning optical instruments (triangulation, confocal, and point autofocus) and areal optical instruments (focus-variation, digital holographic microscopy, phase-shifting interferometry, coherence scanning interferometry).

Another technology used in the industry for measurements in micro and nanoscale is the X-ray computed tomography. See in Picture 2, some graphical illustration with a comparison of the measurement technologies that were already mentioned, it is possible to see that the X-ray computed tomography uses a statistical interpolation to estimate the measurement values, restricting the measurement resolution in some cases.

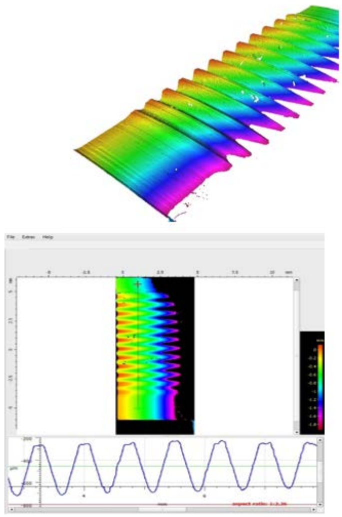


Picture 2 – Different measurement techniques produce different measurement results: schematic representation of (a) tactile, (b) optical, and (c) X-ray computed tomography scanning of a surface. Red lines represent extracted points on the measured surface. Source: Leach et al [6].

CASES/PROJECT PHASE

THREAD CHECK FOR CONCEPT VALIDATION TEST

At the end of the conceptual project several principles should be analyzed, for both control and dimensional verification are the initial step to ensure that the specification is performed as dimensioning. For this, the optical measurement has great versatility, as shown in PICTURE 3 in the verification of a coupling thread.

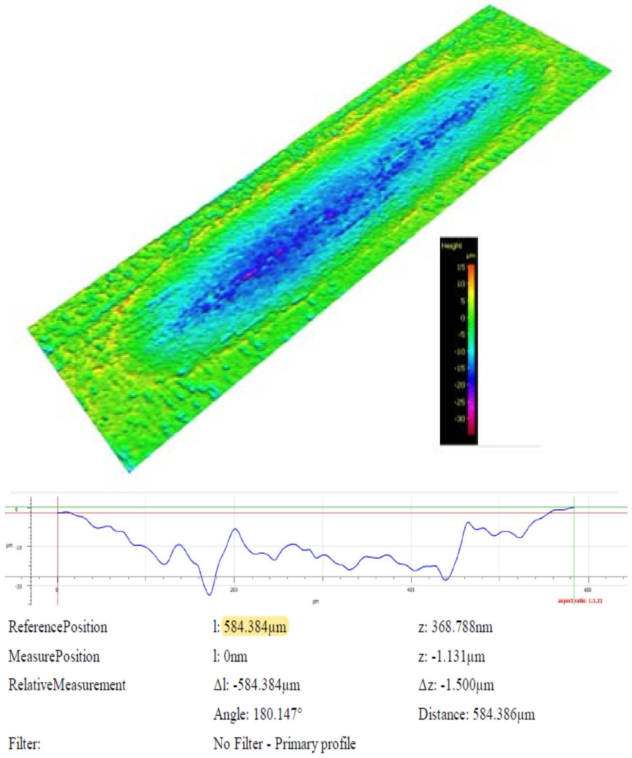


Picture 3 –.Threaded profile checked before concept validation test.

WEAR PAIR

After the generation of concepts, the optimization of materials and processes occurs almost until the end of the development process, as seen in PICTURE 1. After the launch of the product, it can be revised by technological evolution, for example.

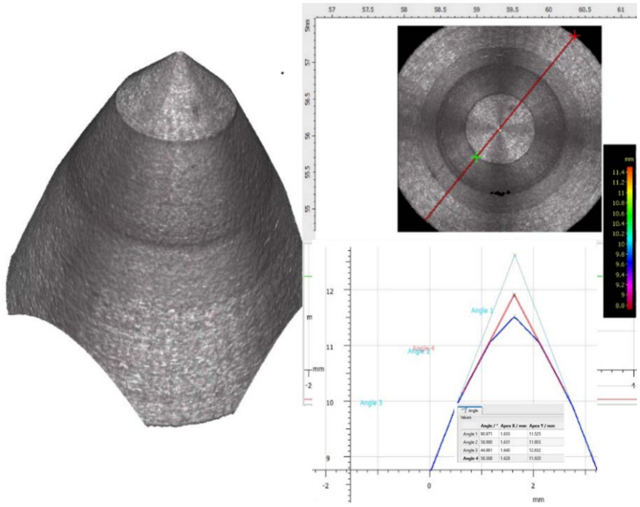
When we talk about wear, we enter the field of tribology and its practices, for example, wear tests. Where the evaluation and classification are done by measuring the volume removed in each tribological pair. PICTURE 4 shows the measurement and characterization of one of these tests.



Picture 4 –.Characteristic tribological test wears track: width characterization.

ANGLE CHECK TO DURABILITY TEST VALIDATION

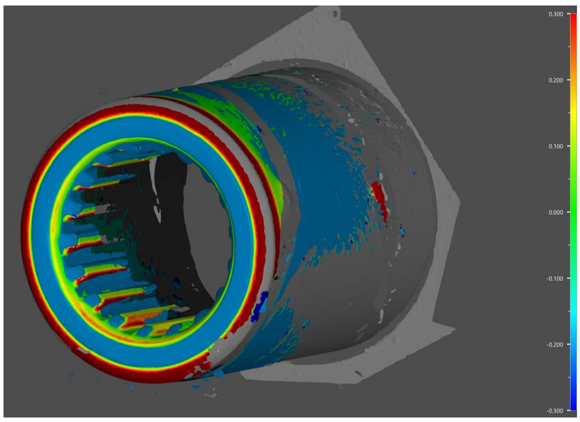
In the field of injection systems, one of the most important elements is the hydraulic seats. Its angles are fundamental in determining the useful life of the components, as well as in the dynamics and hydraulic behavior of the component. PICTURE 5 shows the measurements made in a seat where dimensional control before the execution of a durability test in a proposed sample.



Picture 5 –.Check on seat angles of hydraulic seat proposed before the durability

COMPATIBILITY BETWEEN ELECTRIC MOTOR COUPLINGS

In the search for possible solutions, interchangeability, flexibility, and versatility the confirmation of conformity must be made before the assembly. The example shown here is of different electrical drives, without its coupling specifically. On PICTURE 6 we see the deviation between couplings before assembly for testing. In this case, the time saved with the assembly was used to search for a new solution.

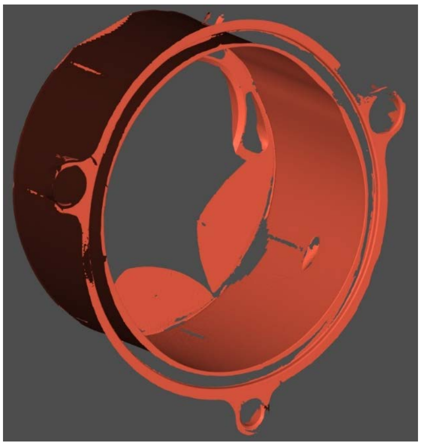


Picture 6 –.Analysis of couplings of different electrical drives.

PROFILE CHECK

After supplier transfer, the validation of the geometry of the cavity of a gear pump needed to be made. Thus, it was performed with the optical measuring equipment, as shown in Picture 7.

This verification was performed for vendor release and verification with the profile specification, as well as with the characterization already produced in another manufacturing plant.

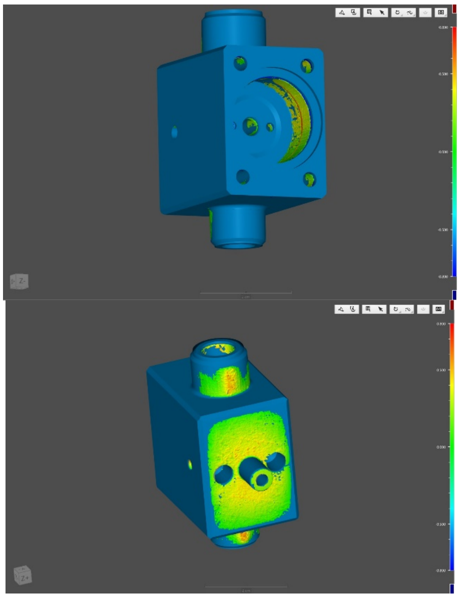


Picture 7 –.Gear pump housing.

ADDITIVE MANUFACTURE VIABILITY STUDY

In this case, the manufacture of a control valve for engines up to 19kW seeks alternative manufacturing processes and additive manufacturing emerged as a possibility.

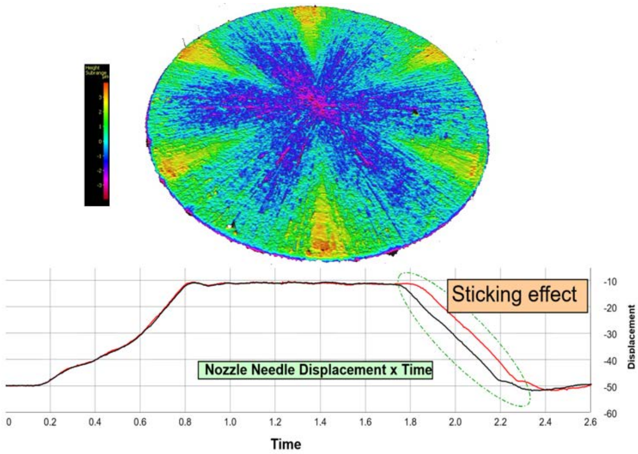
Additive manufacturing has been highlighted as a new reality and two carcasses have been developed. The measurements were made in these carcasses for the understanding of the process and the impact on the final dimensions of the parts. In PICTURE 8, it is observed the divergence is presented with the nominal dimensions.



Picture 8 –.Part deviation made by additive manufacturing of nominal quotas.

SPECIAL PROFILE CHECK MACHINED

In some injectors applications, there is contact between mechanical components that have unwanted adhesion between them. This effect is called “sticking ". To reduce the impact of this effect on the behavior of the Injector and injection, in turn, a shape machining is used at the contact end where this effect is unwanted. On PICTURE 9 we can observe the impact on the movement curve of a needle of an injector nozzle and the impact effect of the "sticking "



Picture 9 –.Contact geometry to avoid sticking, and impact (red) on injection behavior.

CONCLUSIONS

After two years of the beginning of the use of optical measuring equipment a significant impact was perceived by our department. Considerable gains in time and quality of measurement were obtained. The impact on decision making and the gain of versatility in the post-analysis proved to be accurate.

However, a new form of interpretation and understanding regarding measurement and interpretation was necessary, since the amount of information and the form of interpretation is different. There was an increase in the flexibility and versatility of the interpretation of what is measured.

Another advantage of optical equipment is the use of data obtained without mechanical contact. This brings a reduction of costs with parts of the measuring equipment because there is no wear or risk of damage in use.

We have a disruption to traditional measurement methods and the relationship with product development.

For the future, new areas will use this technology in machining tool control and in repetitive measurement processes in production lines, where the automation of the measurement process is allowed, allowing repeatability studies as well.

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