Product design specification methodology for building a device foil incremental deformation by double point method Dieless-DPIF.

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***Abstract*—** The new manufacturing technologies of the world are increasingly demanding the design and redesign of new alternative products and processes that can be useful and low-cost term. The alternative solution and methodology to innovate in manufacturing processes of incremental sheet metal forming is shown in this paper, even the black box for device and functional structure for Dieless process. Through the methodology Product design specification (PDS) as a practical and effective solution, describes the design step, specific requirements, materials and building process to achieve a device´s architecture for a sheet metal deformation by two-point method Dieless - DPIF. The selection, simplification and functionality analysis becomes a fundamental objective for design engineers.

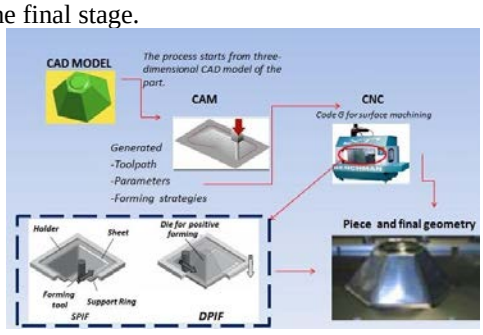
***Keywords*—**Dieless ; DPIF; PDS; PLM ; NPD, Black box

I. Introduction

One of the main design challenges is to achieve convergence of an idea represented in the concrete architecture of it, after the first steps and brainstorming emerged in response to a particular need of the customer or market. The product design specification (PDS) is an initial need for a product designed yet but soon design purposes. The aim is to ensure that the subsequent design and development of a particular product meets the requirements and desires of the end user. PDS is one of the initial and essential in managing the product lifecycle (PLM) elements [1][2]. The application of the design specifications to a particular device as is addressed in this project constitutes the primary object of this work and the result of it is your design for later architecture [3][4]. A flaw in the product specification can lead to failure from the point of view of the user.

Today when trade barriers come down and consumers have the option of choosing the best of the products offered in the market, companies and anyone working in the new product development (NPD -New Product Development) see as priority number one continuous development of innovative and competitive products with excellent design concept. The final goal with this application methodology is to build a device for the Dieless process forming by DPIF[1] method.

Dieless process is done in several stages: it starts with a CAD (Computer aided design) modeling which represents the experimental geometry in three dimensions of the particular piece, the second stage is fed by the CAD file, assigning parameters such as the advance, RPM (Rev/Min), diameter tool, step depth, to a CAM (Computer aided manufacturing) system, you get a programming tool path, expressed in machine code known as G code[2]. This code is entered into a machine with CNC technology which reproduces the toolpath on the surface and deforms the end of the geometry piece, which is the final stage.



[1]**DPIF:** Double point incremental forming, is a method in the Dieless process which combines the CAD design and CAM for achieve incremental sheet metal forming process.

[2] **G-Code:** The G code is a language trough which people can tell computer-controlled machine tools do and how. These "what" and "how" are defined mostly by instructions on where to move, how fast moving and toolpath or follow. Typical machines are controlled is code are milling machines, cutting machines, lathes and 3d printers.

Fig.1. Dieless representative illustration

Black box for device is shown in fig.2, this is very important because the black box is a graphical representation of the main function of the process where the process inputs and the results obtained from these entries are shown. This graph summarizes what the device must meet.

Fig.2 Black box for device and Dieless-DPIF Process

As stated in the black box, the main function of design is to transform or deform a metal foil sheet on a figure, obedient to a specific CAD. What is described below is a protocol of activities to be performed and meet the device in order to perform such deformation.

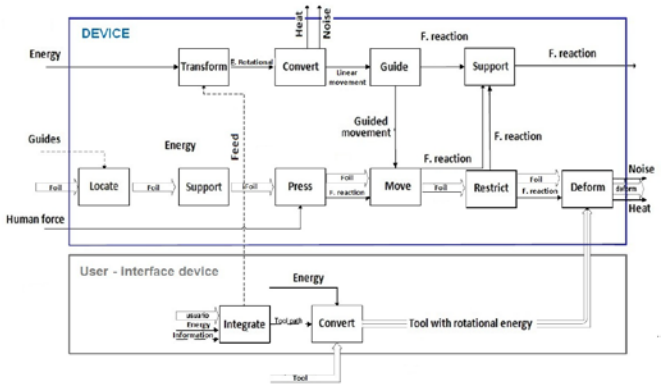


Fig.3. Functional structure for Dieless device

In the functional structure, shown above, is sought from the main function in a group of related sub-functions necessary to fulfill the main function , these subfunctions could be interpreted as gears that are inside the black box necessary for its operation. The functions with their flow are described table I:

TABLE I. MAIN ELEMENTS IN THE FUNCTIONAL STRUCTURE FOR DIELESS DEVICE

Main elements in the functional structure for Dieless Device	
Transform	*This function works with electricity and feed information , either digital or visual . This makes rotational energy , noise and heat .*
Convert	*This rotational movement is converted into a reactions to the structure and the linear motion that moves the mobile plate that holds the blade.*
Guide	*This linear movement must address resulting movement in the right direction and reactions that go into the structure.*
Support	*This is where all the reaction forces of the process and transmitted to ground.*
Locate	*This function is done by human power and guides the information to obtain a sheet located in the correct position.*
Press	*This function has the located sheet and supports a human force that is transmitted by means of screws , resulting in a fixed blade positioned to be deformed .*
Move	*Its entries blade ready to work , a move already addressed by the guidelines and information on the progress required of the mobile plate after trace the outline of each plane.*
Restrict	*This involves helping the deformation of the sheet by means of a mold or partial die restricting the movement of this , leaving reaction forces deform the sheet and others that end up in the structure.*
Deform	*Enter an external element to the device, the tool with the reaction forces generated by the movement restriction device produces a deformed sheet accompanied by heat and noise in the system.*

II. METHODOLOGY

The methodology followed for the initial phase design device starts with brainstorming about the technical requirements to build the device should meet. In figure 2 the initial brainstorming for the initial design device is shown.

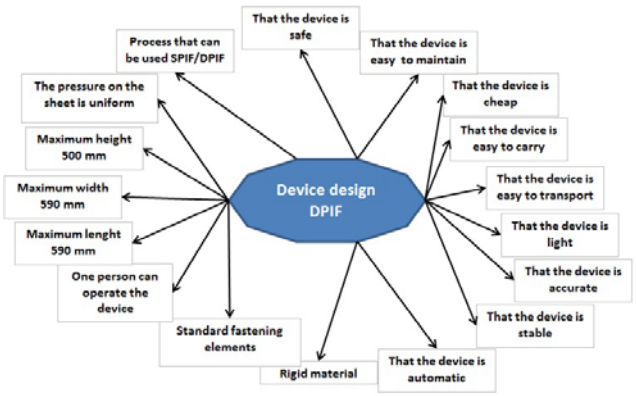


Fig.4. Brainstorming for the initial design

In the mid- 80's in England, Professor Stuart Pugh proposed a model called the Total Design Model in which a thorough knowledge of the market and a through investigation of the needs and users desires were the most important activities before begin establishing technical requirements or design product specification - PDS which in turn was necessary to establish before the conceptualization stage.

According Hollins [5] , this model has been widely accepted in England and some areas have been expanded so that it has become a standard model that serves as a starting point (in the right direction) for the new product development .

An analysis of the Specification or Technical Requirements for Products, made in England, results showed that the main reason for the failure of certain products due to inadequate market research and user requirements that also involved improper setting processes specification.

Based on the pre- project phase formalize the brainstorming is done in PDS format, which is then shown in Tables II-XI.

Model specifications for product design device – PDS

A total of 10 items for the final device construction , they respond to the geometry necessary or desired , specified materials are used, their weight , standard parts , transportation, quality , maintenance , cost, ergonomics and competition.

Geometry: Refers to the general measures of the device.

TABLE II. DESIGN SPECIFICATIONS (PDS) FOR GEOMETRY DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
GEOMETRY	Maximum height: 435 mm	N	That the maximum height not exceeding 435 mm but this measure may decrease.	*Less than 435 mm Height
	Maximum lenght: 750 mm	N	The maximum length not exceeding 750 mm but this measure may decrease.	*Length less than 635 mm
	Maximum width: 590 mm	N	Than the maximum width not exceeding 590 mm, but this measure may reduce	*Width less than 590 mm

Materials: Refers to how the material should be used in the construction of the device.

TABLE III. DESIGN SPECIFICATIONS (PDS) FOR MATERIALS DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
MATERIALS	Rigid material	N	You must use a rigid material for the device construction	*Rigid estructure *AISI SAE 1020 - 8620

Standard Parts: Means that fasteners are readily available on the market.

TABLE IV. DESIGN SPECIFICATIONS (PDS) FOR STANDARD PARTS DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
STANDARD PARTS	That the fixing elements are standard	D	It is intended that the fixing elements are standard for whether to replace quickly any	*Standard clamping elements such as: *Bristol Screw 5x12 M5 *Bristol Screw 6x12M6 * Insertion nut M6 *aluminium cleats.

Quality: Refers to the ability you have to meet the user's needs and have good accuracy of the resulting product.

TABLE V. DESIGN SPECIFICATIONS (PDS) FOR QUALITY DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
QUALITY	The device is stable	N	The device must be firm and stable.	*Stable structure *Symmetry *Flatness and stability in the base *Columns at 90° relative to the base
	The pressure on the sheet is uniform	N	It is intended that the plate that presses the sheet is uniform across the clamping area.	*Uniform pressure
	The device is accurate	N	It is intended that the device is necessary for good results in terms of shapes and sizes.	*Precise movements * There should be synchronization between the CNC machine and the device

Ergonomy: Refers to the comforts and interactions between the product and the user at the time of use.

TABLE VI. DESIGN SPECIFICATIONS (PDS) FOR ERGONOMICS IN THE MANIPULATION DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
ERGONOMY	This device is light	D	Lightweight materials should be used for the construction of the device.	*Light structure, since an operator can load a weight not exceeding 50 kg * Aluminium sections, gives good rigidity and
	That one person can operate the device	D	It is intended that the device is simple and good features indicative for a single person to operate	*Easy to use *One Single operator

Transport: Refers to the facilities to carry from one place to another.

TABLE VII. DESIGN SPECIFICATIONS (PDS) FOR TRANSPORT DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
TRANSPORT	That the device is easy to transport	D	A device that can be easily transported from one place to another is sought.	*Easy transport *Maximum 2 people to transport the device.

Maintenance: Refers to the ease of maintenance of the device.

TABLE VIII. DESIGN SPECIFICATIONS (PDS) FOR MAINTENANCE DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
MAINTENANCE	That the device is easy to maintain.	N	A device to which you can make cleaning and maintenance quick and easy searching. Guided columns must have bushings and bushings system or fat feeding channels to facilitate movement and sliding of the mobile plate .	*Easy maintenance. Fibro sliding sleeve to guide supply channels grease / oil. REF. 2081,84,020
	The device to be disassembled	D	It seeks to disarm the device if you have to do maintenance, replacement of parts and / or redesigns.	*Easy assembly and disassembly. Standard parts, bolts easy disassembly standards (with cordless screwdriver)

Competence: Refers to have an edge over other devices which fulfill the same function.

TABLE IX. DESIGN SPECIFICATIONS (PDS) FOR COMPETENCE IN DIELESS PROCESS

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
COMPETENCE	That can be used for DPIF and SPIF processes	D	A device that can be used both for the SPIF process as DPIF	*Two possible processes on a same device: SPIF / DPIF
	Automatic device	D	A device that is not manual search	*Device managed by CNC numerical control.

Costs: This refers to the cost of building the device.

TABLE X. DESIGN SPECIFICATIONS (PDS) FOR COSTS DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
COSTS	This device is economical	N	It is intended that the design does not cost more than 5.000 USD	*Desired maximum Cost: 5.000 USD

Safety: Means that the device is safe for any environment.

TABLE XI. DESIGN SPECIFICATIONS (PDS) FOR SAFETY DEVICE

ELEMENT	REQUIREMENTS	NEED OR DESIRE	INTERPRETATION	FINAL SPECIFICATION
SAFETY	That is safe for the operator and the environment	N	It is intended that the device does not have sharp edges for operator safety and environment	*Low accident risk for the operator and the environment. Remove edges and edges as far as possible.

Preliminary designs

Were a total of 21 design proposals, based on the specified materials, manufacturability and PDS elements listed above, 2 proposed to be constructed between these same functionality was studied and subjected to several tests were chosen. Different elements are also qualified to select the best design of the device.

As an others research projects, with the preliminary designs, it formed a parametric model with specialized software to build the model, first of all, the principle and validation of motion process is analyzed [13]. Finally, the paper provides the reasonable design parameters according to the above analysis.

III. Results and Analysis

According to the methodology of product design specification (PDS) and the elements that compose it according to the definition given by Stuart Pugh [6], is presented in Table 11, the scoring matrix for the selection of design to comply more closely with the needs and requirements of each of the elements covered in the PDS, this assessment is set according to the level of compliance with these requirements.

TABLE XII. SCORING MATRIX FOR SELECTION OF THE PROPOSED DESIGN DPIF

Scoring matrix for selection of the final design as PDS		
	DPIFN10	DPIFN21
1. Geometry	7	9
2. Materials	8	8
3. Stándard parts	10	10
4. Quality	6	8
5. Ergonomy	5	7
6. Transport	7	9
7. Maintenance	5	7
8. Competence	7	7
9. Costs	7	10
10. Safety	8	8
Total	**70**	**83**

The data presented in Table 11, presented the proposed design No. 21 "DPIFN21" as the most viable alternative and

consistent with the PDS design presented in the methodology and the points scoring (83 pts.) Is the largest of all proposed designs (21 in total). The final designs architectures rated and analyzed in this work are presented in Figures 3 and 4.

Using Creo PTC Software ®, the parametric geometry model is established.

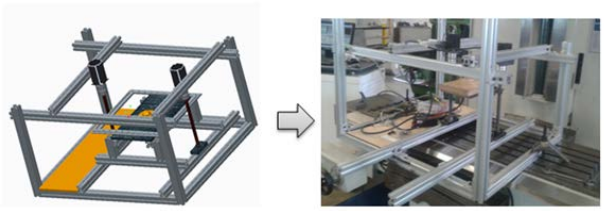


Fig.5. Design proposed No. 10 and device architecture

The design presented in Figure 3, approached the target design and functionality guaranteed Dieless principle incremental deformation of sheet with supporting cast, guaranteed synchrony between the movement of the vertical axis of the device and analog axis to this machine CNC, the movement of the tool also responds from the inside out and from top to bottom, which are fundamental premises Dieless DPIF process.

The design proposal No. 21 has 4 guides in 8620 with 5/10 steel cemented to ensure its hardness and wear resistance by friction between the bushings and guides, a pair of recirculating ball screws to ensure a linear movement high precision and rigidity controlled by two stepper motors obey programmed in a specialized software in computerized numerical control signals.

Fig.6. Design proposed No.21 and final architecture device

The final design presented in Figure 4, due to the different requirements of design and functionality and is the final result of the initial phase of the study project incremental deformation process sheet for double DPIF point support method, currently under development at EAFIT University.

The DPIF device for dieless process with his functionality is shown in the figure below:

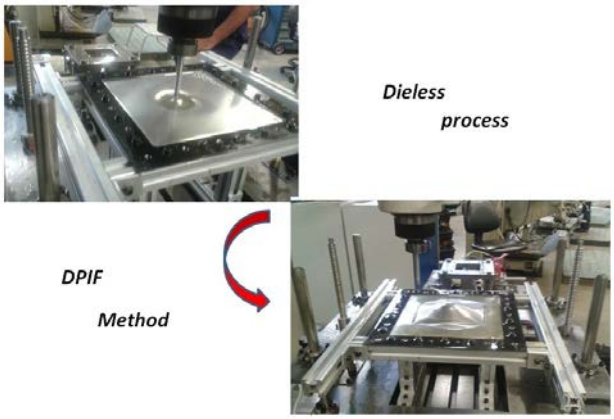


Fig.7. Device for dieless process by DPIF method

A strategy or design methodology describes the general plan of action for a design project and sequence of individual activities that the designer or design team hope to continue to carry out the plan. The purpose of having a strategy is to ensure that activities remain attached to reality with respect to the constraints of time, resources, within which you have to work the design team [10]. With PDS requirements could materialize design ideas and NPD you can select the best option for your final design and his architecture.

Based on the machining conditions of the uses of Dieless device for process deformation, current studies aimed to establish related geometry model for efficiency evaluation and demonstrate qualitative and quantitative analysis by utilizing computer modeling [14].

IV. Conclusions

With the final proposal and system architecture DPIF the initial phase of the study process is concluded by setting the starting point for the study with various geometries and functional prototypes applicable to the process, methodology and / or PDS model based on the principles PUGH were vital to the performance of the device and are applicable to any type of product or machine for industrial purposes. A well-crafted PDS with well-defined technical requirements engineering allow to establish common goals of an interdisciplinary team and its benefits become obvious when conceptualized on very concrete bases.

The PDS is part of the BRIEF, to the extent that these documents are well thought out largely depends on the successful development of a project that culminates in a product having the benefits that users expect to find, especially for the project was crucial as starting point to implement this system in order to ensure a device according to the needs of the end user, who in this case is the investigator DIELESS incremental deformation process.

Dieless device, can be compared with simple industrial robots, they are used largely in manipulation and mounting operations

of a different spares with small and medium dimensions, with regulate forms, which is processed in flexible cells ready in star or circular way of the components. The column industrial robots type represents a large used category, starting with the period of the beginning of automatic flexible manufacture [15]. This comparation is very important because show a wide field in the application for Dieless device in a manufacturing system with flexible manufacture configuration in the near future.

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