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Computer-aided design tool for GT ventilation system ductworks

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ABSTRACT

The design of gas turbine ventilation systems (VSs) is a lengthy and tedious process, often requiring weeks to refine a single design concept and by additional time to manufacture it. This is particularly true when dealing with structural design since the typical approach followed by main worldwide manufacturing companies is to outsource finite elements analysis and, often, the 3d modelling phase itself. Moreover, the structural design process is iterative: the modeling and finite elements analysis steps are repeated several times whenever a new VS has to be produced. Accordingly, speeding-up the structural design phase is today a crucial issue for gas turbine sector. Keeping the above objective in mind, the present paper proposes a CAD-based tool, implemented in a commercial 3D CAD software package (SolidWorks), supporting and partly automating the complex structural VS design process. The solution suggested in this work consists of the design and implementation of a SolidWorks add-in, called *DuctWorks*, developed by using C# programming language. Differently from commercially available solutions, the proposed tool is specifically thought keeping in mind the necessity of performing a final structural assessment, which is of utmost importance given the considerable dimensions and stresses this kind of VS are subject to in the specific field of GT and energy production industry. Tested against a set of case studies, *DuctWorks* proved to be effective in allowing designers to accelerate the ventilation systems design process with excellent results when compared with the traditional design process.

1. Introduction

The proper design of a ventilation system (VS) is an important requirement in the Gas Turbine (GT) and energy production industry in general [15]. In fact, ventilation systems are designed to provide a continuous source of cooling air [6] so as to: remove heat and maintain the air temperature in the compartment below the operating limit; prevent the accumulation of hazardous gases; preserve a constant and uniform airflow through the ducts, independently from the environmental conditions; avoid accidental dust and sand contamination in gas turbines, especially when these are located in regions prone to sandstorm conditions.

When compared to typical Heating, Ventilating and Air Conditioning (HVAC) systems, the design of VSs results particularly challenging since many requirements, generally involving different engineering aspects such as fluid-dynamic, acoustic and structural, have to be fulfilled.

Generally speaking, a VS is composed by a number of elements such as linear ducts, expansion joints, transition duct sections, elbows, outlets to the atmosphere,

supports, saddles and brackets. Shape and dimensions of these elements may significantly vary depending on the kind of application. Basically, the elements may have circular/oval or rectangular/square section. In the first case, they are manufactured by employing calendaring process followed by welding. Otherwise, the component is realized by cutting and welding metal sheets [9, 18]. The entire VS ductwork is assembled by using bolted flanges or welded joints.

The VS design process generally starts from the plant layout definition taking into account a number of design parameters such as location, environmental characteristics, typology of installation (indoor/outdoor), site elevation etc. The plant layout process ends with the draft of a technical drawing of the proposed system including the typology of ducts components (e.g. main duct, branch ducts, expansion ducts and auxiliary components) and the position within the layout of each specific component (with a set of draft dimensions). The subsequent step consists of the fluid-dynamic dimensioning of each component, with particular reference to duct sections (length, cross sections, etc.); a proper dimensioning guarantees

the required flow rate by minimizing friction and pressure losses [5]. Due to the complexity of GT systems, the above mentioned fluid-dynamic dimensioning may be carried out by using 3D CFD analysis [14, 15]; consequently, a simplified 3D model of the ducts need to be obtained by using 3D CAD modelers. Often an iterative procedure is required to determine the duct dimensioning better satisfying design specifications. Once the duct sections are defined, the VS has to be structurally assessed to withstand, with the appropriate safety factors, all possible combinations of mechanical, environmental (i.e. snow and wind) and thermal loads. Structural design, however, requires the definition of materials, the dimensioning of the thickness of each duct component (comprising the coupling flanges) and the positioning and dimensioning of stiffeners. Therefore, usually the structural design phase leads to the creation of a more detailed 3D model, to be used in subsequent FE simulations. The final VS ductwork is obtained after an iterative procedure where the design is possibly changed several times based on the FE results. Only at the end of this iterative procedure, the manufacturing drawings are realized.

According to the above mentioned process, the design of a new ductwork is a lengthy and tedious process, often requiring weeks to refine a single design concept followed by additional time to manufacturing it [2]. Moreover, when dealing with structural design, the typical approach followed by main worldwide GT manufacturing companies is to outsource the phases of 3D modelling, FE analysis and manufacturing. Consequently, a number of SMEs (typically) specialized in this kind of work are involved in the VS design process. In practice, their task consists in repeating the modeling and FE analysis steps several times whenever a new VS has to be produced.

Since the need for greater competitiveness in a global market has increased pressures on companies to reduce design cycles and time-to-market [2], speeding-up even a single step of the complex VS design process is, today, a crucial issue.

Keeping the above objective in mind, the present paper proposes a CAD-based framework supporting and partially automating the complex structural design process. Such a framework comprises: 1) the design and parametrization of VS components; 2) their user-guided assembly and 3) the subsequent FE analysis. Using the proposed framework, it is possible to reduce the time-to-market of a new system and, at the same time, to avoid the necessity of outsourcing structural analysis. From a practical point of view, the solution suggested in this work is implemented in a commercial 3D CAD software package (i.e. SolidWorks). More in detail a SolidWorks add-in, called *DuctWorks*, has been developed by using C# programming language. The choice of SolidWorks as preferred CAD software is mainly due to the fact that it is a widely spread and low cost 3D modelling software featuring an easy to use FE modeler and solver and the availability of a SDK (Software Development Kit) [3, 13, 16]. However, the proposed framework can be easily extended to other CAD software packages sufficient programming capabilities and FE tools.

In detail, such an add-in consists of: 1) an updatable database of custom-designed parametric archetypes (templates) covering the most used components in VS ductworks; 2) an interface to manage/modify the archetypes and to easily assemble the components; 3) an interface to allow (even non-expert) users to simulate the structural behavior in FE environment (i.e. SolidWorks Simulation) taking into account the most common loading conditions.

A huge number of software packages is available on the market dealing the design of HVAC systems, like *REVIT*, *SolidWorks Routing, Design Master HVAC, CATIA – HVAC* and *Creo CADDS 5 HVAC* just to mention a few. However, to the best of authors' knowledge, these tools are oriented towards layout design, schematics generation, pressure losses computation, collision detection, BOM reports and many others but do not allow structural analysis. Conversely, the proposed tool is specifically thought keeping in mind the necessity of performing a final structural assessment, which is of utmost importance given the considerable dimensions and stresses this kind of VSs are subject to in the specific field of GT and energy production industry.

2. Archetypes database

With the aim of designing a customized tool able to speed-up the assembly of ducts and, at the same time, to allow a fast FE analysis, the first step is to build a database of components typically making up a VS.

The database has been developed by preliminary analyzing a set of projects from SMEs producing VSs for the leading Oil and Gas companies operating worldwide. Despite the complexity of VS, consisting of a great number of different components with different shapes and dimensions, it is possible to classify such components into a limited number of categories. In fact, often 15–20 categories are sufficient to fully describe the entire set of modules composing a VS. By way of example, into a branch of the VS it is possible to use many straight ducts characterized by different sections, lengths and stiffeners (elements necessary to improve the stiffness of the module); however, the geometry of such a duct is clearly the same. Analogous considerations can be made when referring to other components (e.g. curved ducts and outlet ducts). Accordingly, it is possible to define a set

of archetypes (i.e. parametric models) covering all the possible modules composing a typical VS.

Consequently, a database collecting a number of archetypes to be subsequently added to an assembly, has been developed. To demonstrate the effectiveness of the entire proposed tool, the database has been populated with the following eight duct archetypes. These, all characterized by a rectangular/square section, have been found to be the most recurring ones: Straight (Fig. 1(a).); Elbow TypeA (Fig. 1(b).); Elbow TypeB (Fig. 1(c).); Curved (Fig. 1(d).); Transition (Fig. 1(e).); Offset (Fig. 1(f).); Three Way (Fig. 1(g).); Outlet (Fig. 1(h).).

The most challenging task to create a consistent database is to select the best set of parameters fully describing the archetypes. Fortunately, this task is eased by the experience of the SMEs designers that are aware of the typical CAD task sequence to create the customized modules. Following their guidelines, the above mentioned ducts can be basically modeled, within the CAD environment, as follows:

-   *Straight*: consists of a straight duct obtainable by extruding a rectangular section along a line.
-   *Elbow TypeA*: consists of a 90° curve where the section is obtainable as a sweep of a rectangular section along a given path (consisting on two straight lines and a 90° curve).
-   *Elbow TypeB*: consists of a duct obtainable as a sweep of a rectangular section along two orthogonal segments and by filleting, using two different curvature radii, the two sharp edges.
-   *Curved*: consists of a curve where the section is obtainable as a sweep of a rectangular section along a given path (consisting on two straight segments

and a curve with a given angle strictly lower than 90°). Even if the *Elbow TypeA* could be considered a particular case of this archetype, they are typically dimensioned in a different way so that it is not possible to use a single archetype for modelling both.

-   *Transition*: obtainable by means of a loft between two differently sized rectangular sections.
-   *Offset*: obtainable by means of a sweep along a path consisting of a straight line followed by an inclined line finally connected with another straight line.
-   *Three Way*: obtainable as a combination of the *Straight* duct and the *Elbow Type A* duct.
-   *Outlet*: obtainable by cutting a straight duct with an inclined plane.

Moreover, even if the geometry of the archetypes is considerably different (even reducing the choice to only 8 categories), they share some common characteristics:

-   flanges are manufactured by using L-shaped bars (flanges);
-   when the area of a duct wall exceeds $0.8\,m^2$ one or more stiffeners are added to strengthen structural behavior;
-   thickness is always equal to or greater than 3 mm;
-   components material is steel.

Consequently, each archetype can be defined by a set of parameters taking into account not only geometrical properties but also the presence of stiffeners (number and dimensions) and the structure made of L-shaped flanges.

For sake of clarity, referring to the Curved duct of Fig. 1(d), the parameters used to fully describe the archetype are (see Fig. 2.):
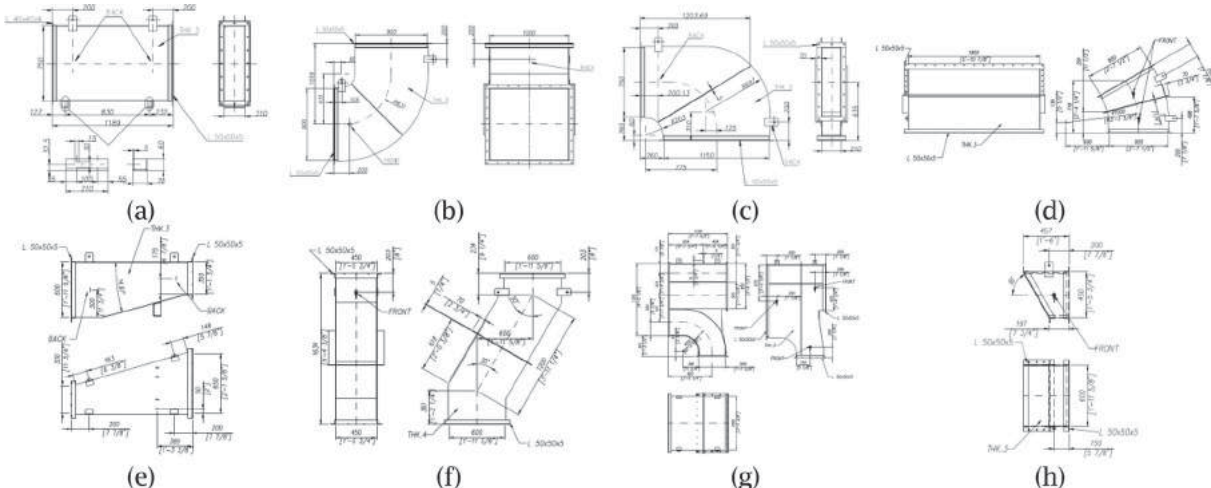

Figure 1. Archetypal components of the ventilation system selected for the definition of database.
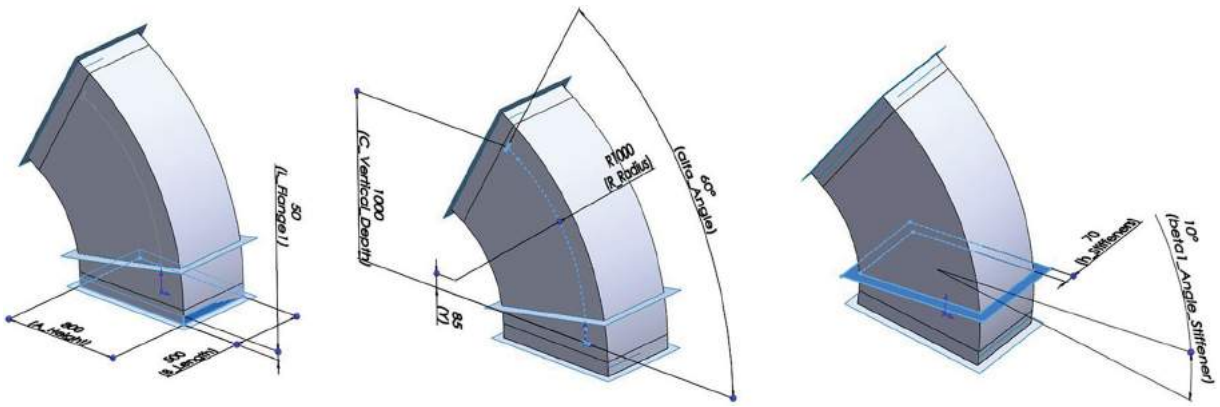
Figure 2. Parameters defining the *Curved* duct.

- 7 geometric parameters: height (*A_Height*), length (*B_Lenght)*, curvature angle (*alfa_Angle*), curvature radius (*R_Radius*), vertical depth (*C_Vertical_Depth*), curvature center position (*Y*), and thickness (*t1)*.
- 4 parameters related to L-shaped flanges: dimensions (*L_Flange1* e *L_Flange2)* and thickness (*tf1* e *tf2)* of the two L-flanges composing the duct section. Both data are selected among the standard available in the market.
- From 4 to 7 parameters related to the stiffeners: stiffener extension (*h_Stiffeners)*, thickness (*ts*), number of stiffeners (*ns*), angle defining the position of each stiffener. For this archetype the maximum number of stiffeners is equal to 4; as a consequence the number of editable angles is, at most, equal to 4 (*beta$_i$_Angle_Stiffener*, with i = 1:4).

As recognized by literature works [4, 10] the typical output of computer-aided geometric design system is not straightforwardly suitable as a direct input for finite-element modeler since they inherently use different types of geometric models [12]. In fact, typical FE analysis requires simplified models to be performed. To solve this issue, common methods based on feature recognition [7], detail removal [11] and dimensional reduction [17] are available in scientific literature. Alternatively, many of these difficulties can be reduced by implementing a unified representation paradigm i.e. "an environment in which the geometric model uses the same underlying representation as the appropriate finite-element simulation" [4]. Inspired by this category of methods, in this work the archetypes are built keeping in mind the FE requirements. First, the eight ducts have been modeled using surfaces instead of solid, so that shell elements, which are known to be a good option for FE simulation of thin-walled structures [1] and suitable for this specific application, can be used. This, moreover, allows to keep the FE simulation time as short as possible. Then, VS branches are modeled by directly using simplified archetypes without small chamfers, fillets and holes.

Consequently, the proposed modelling strategy allows to directly perform the FE simulation on the resulting 3D model without the need of any model updating process. Especially considering that the design process is often iterative, this feature is extremely relevant for speeding-up the design process.

In Fig. 3. the 8 parametric archetypes populating the database are shown.

Once all the archetypes are properly modelled, an appropriate *Property Manager* page is built in order to allow users to manage all the parameters previously defined. In Fig. 4. the *Property Manager* for the *Curved* duct is depicted. The manager is structured in three sections to cope with the geometric dimensions, the L-shaped flanges and the stiffeners.

Referring to the L-shaped flanges, it is possible to define equal or different dimensions for, respectively, the inlet and outlet parts of the duct. For parameters to be selected among standard dimensions (e.g. for the L-shaped flange dimensions and thickness) a selection menu (*ComboBox*) is made available. Dealing with stiffeners management, it has to be considered that the default option is to use the archetype without any stiffener. Once the user selects one or more stiffeners, the CAD model is updated to include them. This update is possible since all the envisaged stiffeners are always modelled in the archetype, but results under suppression state in the feature tree; when the user select the stiffener checkbox and decide the number of them, the suppression state changes in unsuppressed. It is important to note that an update of the database with new archetypes necessarily involves also the definition of a new *Property Manager*.
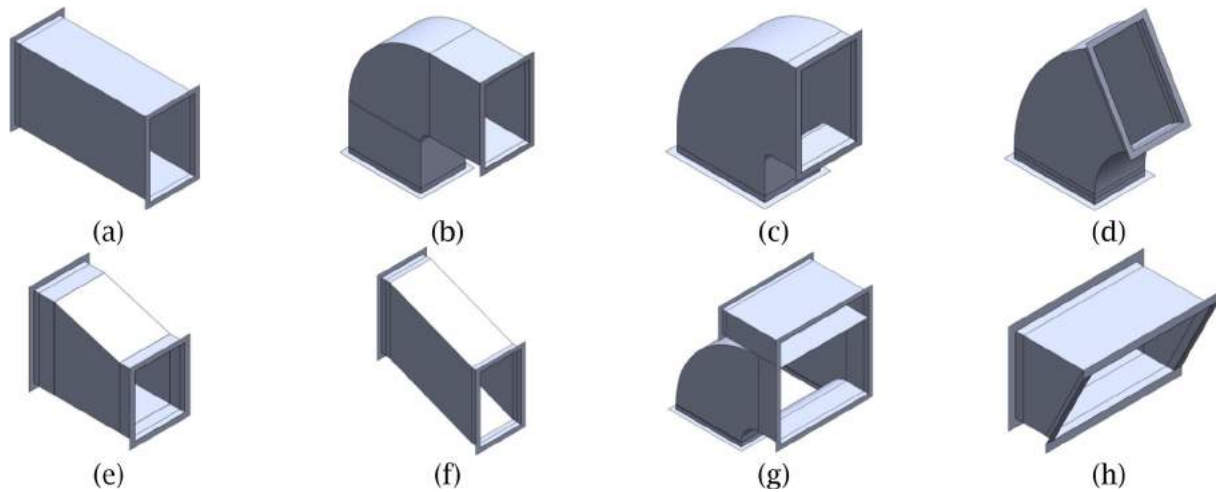
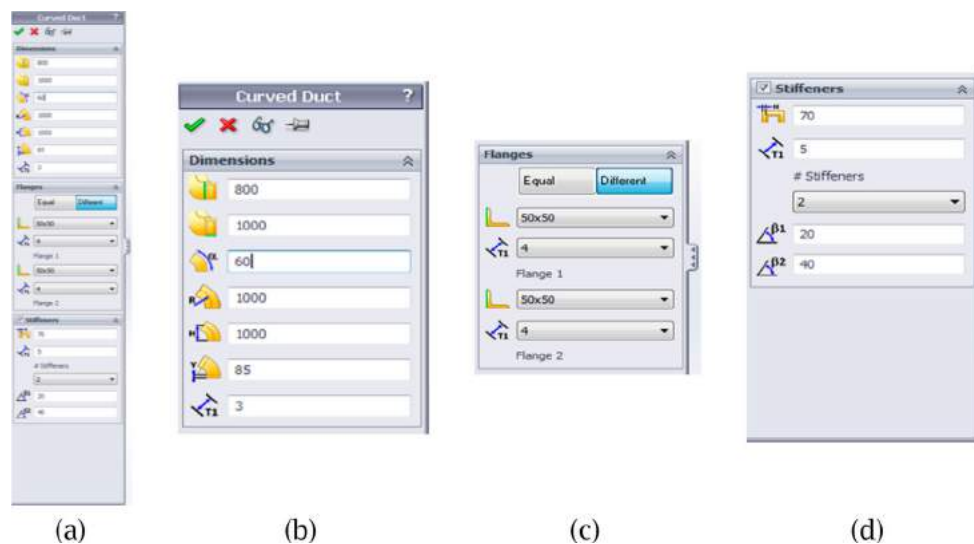**Figure 3.** Parametrized archetypes populating the database.

Figure 4. Example of *Property Manager* page related to *Curved* duct (a); section for dimensioning: (b) the main geometry of the duct, (c) the L-shaped flanges and (d) the stiffeners.

3. Ductworks functionalities

The main idea behind the developed tool (*DuctWorks*) was to create an instrument (add-in) similar to any Solid-Works Toolbox® (used for instance to manage bolts, screws, washers, nuts, bearings, etc.) i.e. to include the library of duct parts within CAD software. Accordingly, the tool has been designed to manage and modify each module and the assembly of archetypes. Moreover, the tool is designed to guide the user to perform the FE analysis by using the SolidWorks Simulation add-in. Therefore, *DuctWorks* functionalities, developed by means of the SolidWorks API SDK (using C#), are:

- Management, modification and assembly of archetypes
- Guided FE analysis

3.1. Management, modification and assembly of archetypes

As soon as the archetype database and the related *Property Manager* pages are built, the assembly of a new duct can proceed straightforwardly. In fact, the entire VS ductwork (or one of its branches) can be easily modelled by means of a step-by-step procedure.

After dragging and dropping the first desired component (see Fig. 5(a).), the *Property Manager* page, referred to the selected component, is displayed in the corresponding tab (to the left side of the graphic area) enabling the user to possibly modify all the model parameters.

Moreover, *DuctWorks* checks the consistency of user-defined dimensions and suggests to insert one or more stiffeners in case the area of one of the metal sheets exceeds 0.8 m^2 (see Fig. 5(b).). This control is
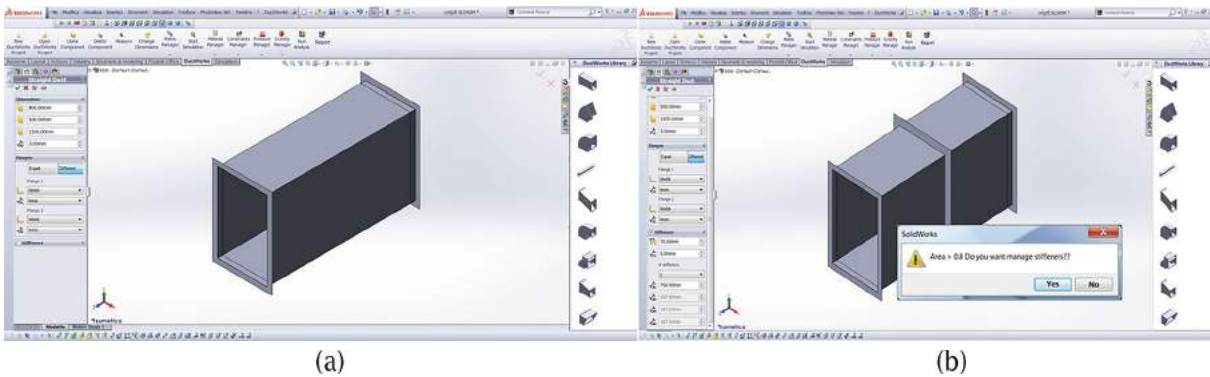
Figure 5. *DuctWorks* add-in: a) archetype database on the right and Property Manager on the left of the graphics area; b) a pop-up menu suggesting to insert one or more stiffeners in case the area of one of the metal sheets exceeds 0.8 m^2.

recommended since it has been demonstrated, by the experience of the leading companies in the O&G sector, that for walls characterized by thickness equal to 3mm and realized in S275JR steel (i.e. for the most common manufacturing characteristics of commercial ducts) some structural issues may arise.

Only after the first element is properly modelled, the following ones can be inserted; the tool automatically recognizes if a previous element has already been defined, so that it allows, not only to dimension the new one (using its *Property Manager*), but also to insert all the necessary mates to correctly assemble the two elements. In particular, only a subset of mates among all the available in SolidWorks (i.e. face, edge, vertex coincidences and reciprocal distances) is selectable by the user so as to facilitate the mating process also for non-expert users. Moreover, *DuctWorks* is able to check if the selected mates are sufficient for fully defining the relative position of the components; in case the check fails, the tool iteratively asks the user to insert more mates.

This procedure can be repeated until the entire VS ductwork (or one of its branches) is designed (see Fig. 6.). As described above, since the devised tool is
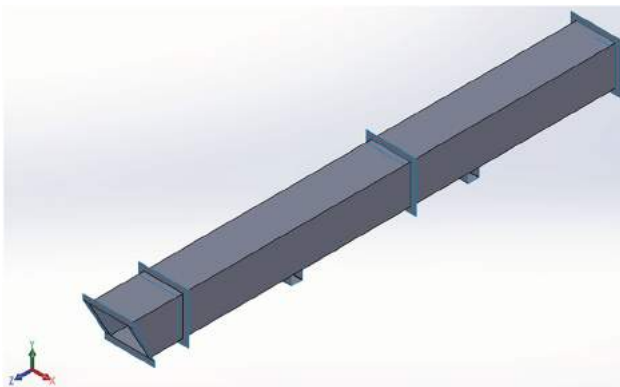

Figure 6. Assembly of a VS branch designed with *DuctWorks*.

fully integrated within the CAD environment, the user can change properties of the components at any time, if required. In fact, the dedicated *Property Manager* pages for managing dimensions and mates can be always activated by using an appositely devised *toolbar*. The final design of the VS can be finally enriched by adding all support systems (e.g. brackets) necessary to apply the constraints for FE analysis. In the devised tool even such supporting components have been added to the database, to further speed-up the process.

3.2. Guided FE analysis

Differently from other commercial tools, *DuctWorks* directly provides a toolbar for carrying out a step-by-step FE simulation of the assembly taking into account a variety of load cases. As mentioned in Section 2, archetypes are built so as to avoid the necessity of manually updating/changing the starting geometric model (i.e., for instance, there is no need to convert solid parts into surface ones by extracting mid surfaces).

The designed graphical user interface makes available to the final users only the essential commands to set up and run the FE simulation on this type of ducts. In particular, the user is allowed to limit the choice of loads only to pressure (to consider the duct internal gas pressure or the external loads due to snow and wind) and gravity and to select only constraints to fix faces, edges and vertices. The thicknesses of the shells, composing the designed VS, are automatically set taking the corresponding values (pre-set by the user during the assembly phase) from the *Property Manager*. A menu for defining the material is also provided by the tool. Contacts between surfaces of adjacent parts are automatically set to "bonded" [8], under the simplified hypothesis that the junction element (welding or bolt) is sufficient to guarantee the seal. This exemplificative modelling is reliable also for bolting connections since a redundant number
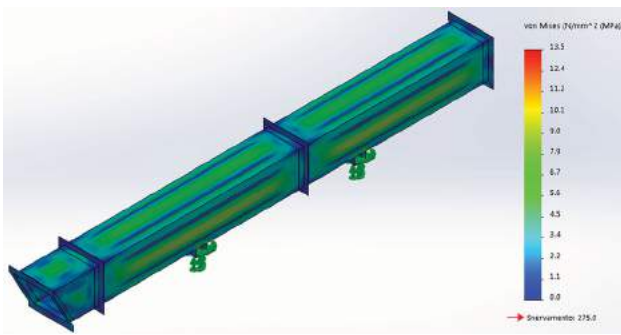
Figure 7. Von Mises stress map simulated using *DuctWorks*.

of bolts is commonly used to join the parts. Moreover, the same strategy for modelling this contact is followed by outsourced companies carrying out the FE analysis. Since such a FE analysis provides reliable results when compared to actual behavior of the VS, this assumption can be considered valid.

In order to guarantee that all the necessary step for performing the FE are completed, the pushbutton (to start the FE analysis) is activated only after the user has properly set materials, loads and constraints. Once the pushbutton is activated, an appositely devised property manager for mesh management starts. Since the tool is devoted to non-expert users (especially in FE analysis) the manager does not allow to select the shell type that is automatically set to parabolic triangular shell elements (6-node elements). Such elements are 2D elements capable of resisting membrane and bending loads [8] and therefore are appropriate for the specific application. Moreover, users can select the average edge length of shell elements between a minimum of 10 mm to a maximum of 60 mm (i.e. a range typically used for FE analysis of VS systems).

The guided and easy to use FE part of the tool is a considerable improvement with respect to other available commercial tools and is achievable only thanks to the careful geometric modeling phase carried out during archetype development mentioned before.

By following the described procedure, even a non-expert user is able to straightforwardly simulate the structural behavior of the VS ductwork. The outputs of this analysis are the Von Mises stress map (see Fig. 7.), the total displacement map and the displacements along the three orthogonal directions (X, Y, Z).

4. Results

To evaluate the effectiveness of the designed tool, a number of case studies provided by a Company operating in Italy in the Oil and Gas sector have been analyzed.

More in particular, a set of 10 already designed and verified VS ductworks have been considered and have been re-modelled and simulated by using the proposed tool, under the load conditions stated by Company technical datasheet. The FE simulation results obtained using *DuctWorks* have been, then, compared with the ones previously obtained following the traditional design process. Two representative case studies are discussed in this section to demonstrate the potential of the developed tool.

Case study 1

The first case study (Fig. 8.) is a gas turbine compartment inlet duct. It is composed by a *Straight* component, an *Elbow TypeA* duct and a *Three Way* element.

Original design of this ductwork was made by a CAD expert that worked for about 3 hours to create the assembly. Such a CAD model has been outsourced for FE analysis and the final results were available to the Company after a week. In this case the design did not require any iteration; accordingly, the whole design process time can be estimated in about a week.

Using *DuctWorks*, another CAD expert (with analogous expertise) designed and simulated the branch in less than half an hour. Even considering that the timing for outsourced FE analysis is not process times (i.e. they are mostly "market times") and that actual process for FE analysis can be estimated in 1 hour, the use of *DuctWorks* allows a time reduction equal to about 87%. This demonstrates that the use of the proposed tool is time effective. To assess the consistence of FE analysis in terms of Von Mises stresses and total displacement, results obtained using *DuctWorks* have been compared with the FE results provided by the outsourced company. The FE analysis was conducted under the conditions listed in Tab. 1 (coming from Company technical sheet). It is worth noting that the FE simulation is carried
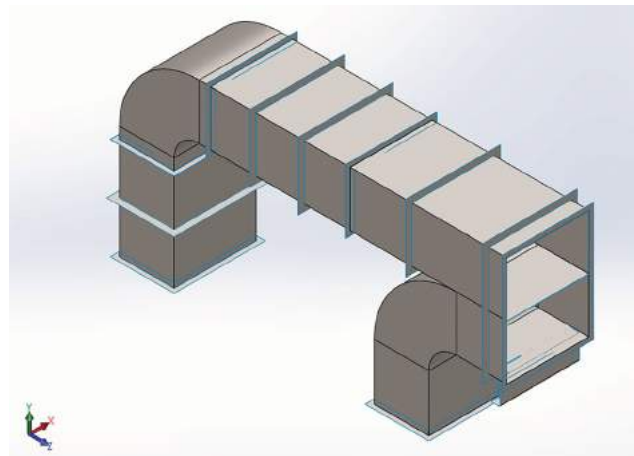

Figure 8. Case study 1: gas turbine compartment inlet duct.

Table 1. Material for modelling the VS and applied loads.

Material	AISI 316L
Design internal pressure	3000 N/m²
Gravity	yes

Table 2. Comparison between the maxima values of Von Mises stress and total displacement obtained using *DuctWorks* and the ones from the outsourced company.

	FE analysis using *DuctWorks*	Outsourced FE analysis	E_{Ass}	$E_\%$
Maximum value of Von Mises stress	53.2 MPa	48.9 MPa	4.3 MPa	8.8%
Maximum value of total displacement	7.3 mm	6.8 mm	0.5 mm	7.4%

out without considering the contribute of temperature, since expansion joints are assembled at the branches extremities to compensate possible thermal expansions. Nonetheless, *DuctWorks* allows also to introduce thermal loads.
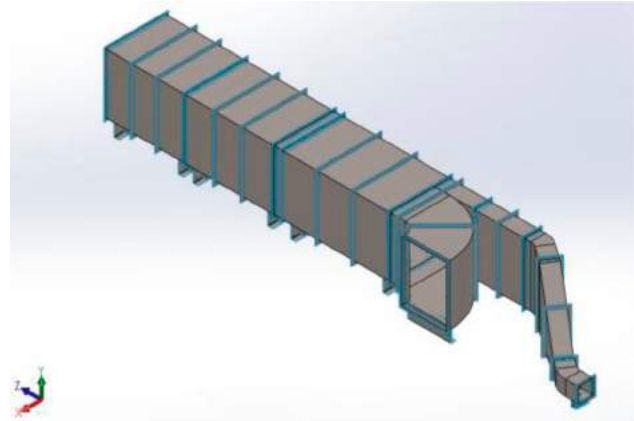
Results of the FE simulation obtained by using *Duct-Works* are in Fig. 9. These have been compared with the outsourced ones. The comparison showed that the Von Mises stress and total displacement maps are quite similar and the position of the maxima values are approximately the same. Outsourced FE results are not shown since they are confidential and the Italian company providing the test bed for the devised tool does not authorize their distribution. The comparison between the maxima values of Von Mises stress and total displacement with the results coming from the outsourced company is provided in Tab 2. Since the FE outcomes are comparable, *DuctWorks* proves to be effective also in terms of performance.

Case study 2

The second case study (see Fig. 10.) is an inlet duct second branch of a VS composed by three *Straight* components, a *Three Way*, a *Curved* component (35°), a *Transition* and two more *Curved* components (35°). In addition, in this case a comparison between traditional design process and *DuctWorks*-based one is provided. The outsourced FE analysis (under the same conditions stated in Table 1) has been conducted twice, since one of the originally designed *Straight* components was excessively stressed by the internal pressure. For this reason, the overall process time was estimated in about 8 hours. Quite the reverse, the necessity of performing a CAD modification and two FE analysis using *DuctWorks* does


Figure 10. Case study 2: gas turbine inlet duct second branch.

not raise considerably the overall process time (less than 15 minutes more). This further demonstrates that the devised tool is really helpful for designing new ducts.

Also in this case the FE analysis coming out from *DuctWorks* (see Fig. 11.) is comparable with the one outsourced by the company (see Tab. 3.).

5. Conclusions

The present work proposes a novel tool, called *Duct-Works*, providing a CAD/FEM solution to designers of VS ductwork (specifically devised for the GT sector and energy production industry). The tool operates within
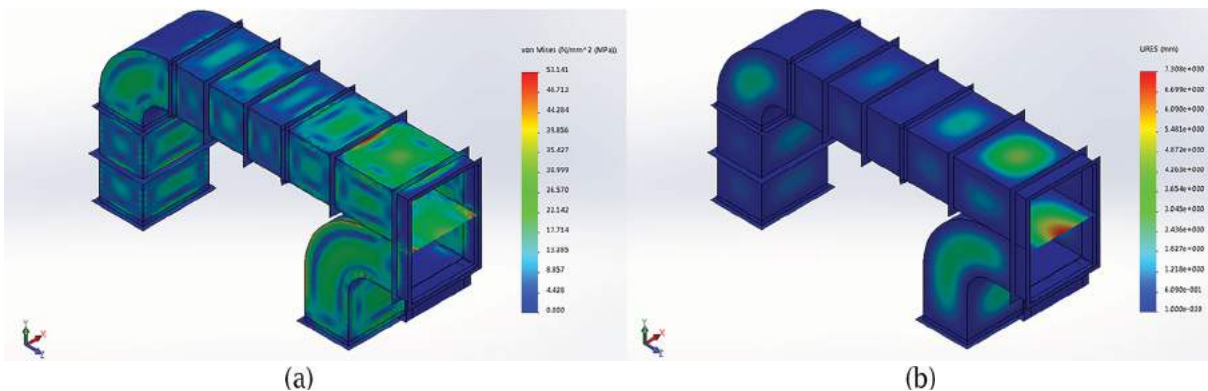
Figure 9. FE analysis conducted on case study 1 using *DuctWorks*: a) Von Mises stress map; b) total displacement map.
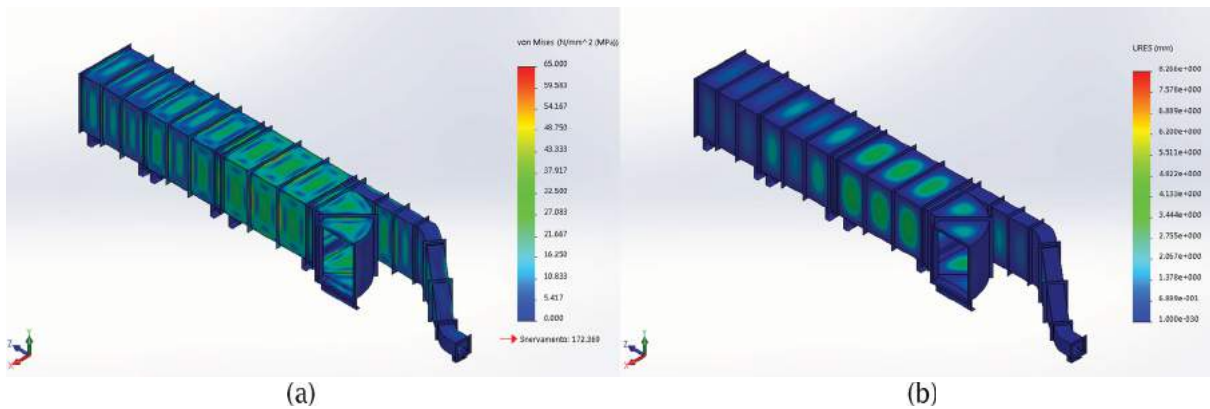
Figure 11. FE analysis conducted on case study 2 using *DuctWorks*: a) Von Mises stress map; b) total displacement map.

Table 3. Comparison between the maxima values of Von Mises stress and total displacement obtained using *DuctWorks* and the ones from the outsourced company.

	FE analysis using *DuctWorks*	Outsourced FE analysis	E_{Ass}	$E_\%$
Maximum value of Von Mises stress	64.1 MPa	62.7 MPa	1.4 MPa	2.2%
Maximum value of total displacement	8.2 mm	7.8 mm	0.4 mm	5%

the SolidWorks platform and relies on the construction of a database of archetypes. The tool allows to speed-up the modelling and modification of ductwork components and assemblies as well as to provide a semi-automatic and intuitive FE analysis environment, which directly operates on the geometry coming out from the modeling phase (differently from other commercial solutions such as SolidWorks Routing).

By analyzing ten case studies, a mean error of approximately 5% in terms of maximum values of Von Mises stresses and 7% error in terms of maximum value of total displacement can be observed. These values can be considered more than acceptable, even more considering that the comparison test is between two numerical simulations and therefore there is not guarantee that outsourced results are more reliable than *DuctWorks* ones. Accordingly, with similar FE results, the proposed tool has the unquestionable benefit of being time-effective since a typical CAD user (not particularly skilled) is able to complete the entire process in only a fraction (typically 15%) of the time commonly spent on this kind of work.

The main drawback of the proposed tool relies in the necessity of populating the archetype database to include all possible models used for a specific application. In fact, the issue here is not related only to the CAD modelling of the archetype (thus including parametrization) but also on the fact that for each added archetype,

the correspondent rules for its property setting manager have to be defined. As a consequence, it becomes crucial for SMEs willing to use (and to update) *DuctWorks* to spend their expertise in deciding the best strategy for parametrizing their own models. It has to be considered, however, that the time spent for updating the database is not a design process time and, therefore, it could be worth spending resources to increase the number of models into the database especially when the subsequent design process is proven to be extremely reduced. Moreover, it has to be highlighted that, as mentioned in the introductory section, the tool allows only to perform structural analysis since it does not encompass fluid-dynamics analysis. This is mainly due to the fact that the modeling simplification strategy is dedicated to structural analysis. Nonetheless, a similar approach could be used for other analysis under the condition that the CAD modelling preparation is specifically modified.

In future works the authors will study the feasibility of a guided procedure to assist CAD designers during the definition of the required rules for consistent population of the database.

Future works will be addressed to find a set of strategies to possibly reduce archetype definition (e.g. to find a set of common rules, similar to the ones depicted in Section 2, to be applied to a majority of models) and to add more functionalities such as fluid-dynamics or thermal analysis. Furthermore, the proposed tool could be easily extended to similar application fields such as, for instance, the modeling and structural analysis of air conditioning systems.

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