

REDESIGNING THE CYCLONE SEPARATOR EXPANSION TO MAXIMIZE PROCESS EFFICIENCY

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ABSTRACT

The paper examines the specific characteristics considered when determining the amount of sheet material necessary for the manufacture of machine parts with a predominant number of sheet material components. Pointed out is the possibility to optimize material consumption at the stage of design by incorporating the capabilities of AutoCAD software. Research conducted revealed that the quantity of material with a predominant number of sheet material components, such as a cyclone separator, is increasingly subject to the accuracy of cutting and positioning of workpiece unfolding on the sheet material, which is ultimately related to the increased process optimization.

Key words: AutoCAD, Cyclone Separator, Expansion, Optimization, Sheet Material.

INTRODUCTION

In various sectors of mechanical engineering such as light industry, manufacturing, food industry, agricultural engineering, construction, pneumatic and hydro transport, etc., parts or composite products are often designed using sheet material. Manufacturing involves cutting the workpiece manually, semi-automatically, or automatically along the line of unfolding. Composite products are produced through welding, gluing, fixed (e.g. rivet) or detachable (e.g. bolt, screw, stud) joining or other methods relative to their designated use and ensuring their strength, tightness, and robustness.

Due to the fact that the production is singular and in small batches, the lack of technological documentation, process, and route maps does not present a barrier to the manufacture of the machines under consideration. The primary task in the production of machinery and equipment with a predominant number of sheet material components (which are not standardized purchase products, complete set or cooperated products – blanks) is determining the appropriate type and quantity of the sheet material necessary for the manufacture of these parts. To that effect, it is imperative to establish the unfoldment areas of both the sheet metal workpieces (tin) and those of the sheet metal workpieces of the machinery and equipment with a predominant number of sheet metal components, with reference to the relevant technical documentation, which, however, tends to be inconclusive and insufficient in terms of the technological waste generated during production (Bankova, A. et al., 2023; Bankova, A. et al., 2024; Mihaylov R. et al. 2021.). It is crucial, therefore, to calculate the proportion of the technological waste in order to increase the quantity of the sheet material necessary for the manufacture of the sheet material (tin) components of the machinery under discussion accordingly.

The primary step in the fabrication of every sheet metal component is acquiring the correct unfolding. Various factors should be considered during unfoldment: for example, when bending, it is necessary to include the thickness of the sheet, the angle of bending, the plasticity of the material, the preparation of the ends to be joined consistent with the specific methods of joining, and even the qualities of the sheet material itself (Radin A., Korschunova, D., 2009). Due to the

significant technological waste in the manufacture of sheet metal parts and products, which can reach up to 20%, and even more in some cases, particularly in the case of rotary parts, it is extremely important to optimize the sheet metal cutting, which is largely subject to the unfolding of the parts, the number of products under manufacture, the dimensions of the sheet material and in some cases, it may be even necessary at the design stage to change the way the composite component parts are connected (Boothroud, G. 2005; Dimitrov, L. 2009). To address the challenges associated with material planning and supply, and their full utilization, the present paper introduces a different perspective on the implementation of a graphical CAD system – AutoCAD (Anurev, V.2003; Groove, M., 2008; Sirmanov, V., 2009; Dimitrov, Yu., et al., 2016; Barbieri, G. et al., 2014).

MATERIALS AND METHODS

Cyclone design and development expansion

The cyclone depicted in Figure 1. is specifically designed for the separation of suspended dry dust particles from gas environment, that are generated in various grinding and crushing plants, during the transportation of bulk materials, and in the handling of fly ash. Cyclone CN represents the most basic type of air purification device, constructed from a cylindrical body, a lower conical section and an internal exhaust pipe. The operating principle of the filter is based on the radical vortex of suspended particles, which lose their kinetic energy when colliding with the inner walls of the cyclone, and once collected in the dust collector, they eventually settle down under the influence of gravity. The dusty air enters the cyclone body through the spiral, while the purified air exits upwards through the exhaust pipe. The effectiveness of gas mixture purification is contingent upon several factors, including the angle of inclination of the vortex, the dimensions of the cylindrical and conical body, as well as the angle of the spiral.

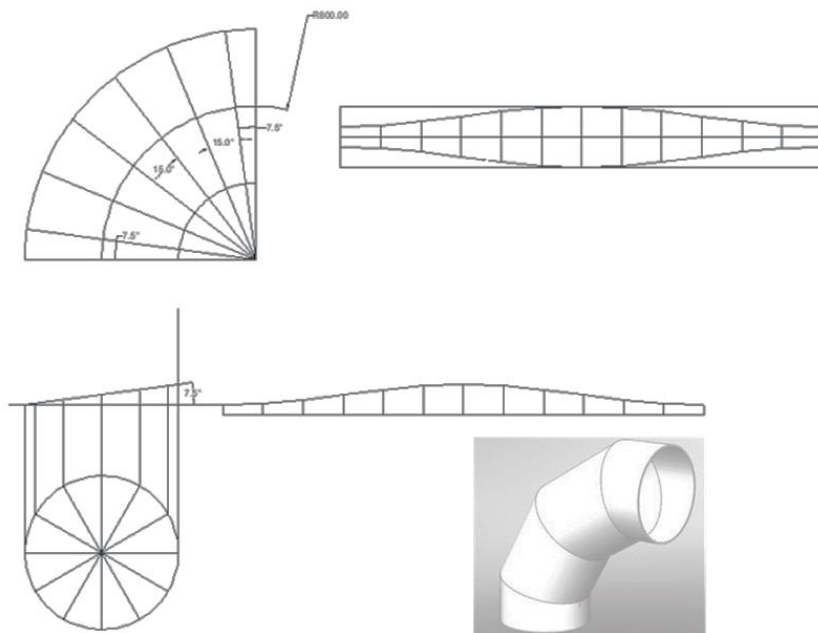


Figure 1: The expansion of a part of a toroidal surface with a meridional cross-section is an arc of an arbitrary curve (<https://v-klapan.by/>; <https://sibelkon.ru>)

Problems frequently arise, in practice, when cutting and creating parts, even with those whose surfaces should be easy to unfold. Our primary focus, therefore, will be on identifying and analyzing some significant obstacles by closely examining a specific cyclone structure, whose pivotal component, the crank mechanism, forms an essential part of the toroidal surface depicted in Figure 2, providing a detailed view of the unfolding of a segment along a toroidal surface featuring a meridional arc section of random curve. The crank mechanism represents a quarter of the torus with a mean radius of 800mm and a forming circle diameter of 800 mm. The study explores a cyclone component with set dimensions in order to draw valid conclusions about certain inaccuracies identified in the process of unfolding and to provide recommendations for improved accuracy and prevention against faulty experimental samples (trial component). It is important to note that the present study does not probe into helicoids or helical (blade) surfaces, which are examples of surfaces that cannot be unfolded and are commonly used in various fields of practice. Such surfaces are, for instance, applicable in screw conveyors, agricultural seed cleaning plants, sieve hullers, calibrating machines, trieur sorting equipment, and others. These surfaces will be addressed in future research and design considerations.

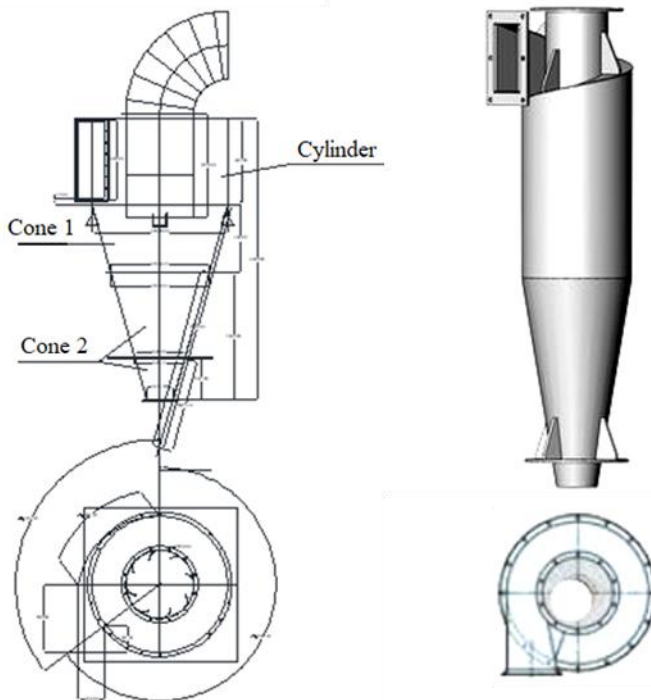


Figure 2: Scheme and 3D of a cyclone

Unfolding non-expandable second and higher-order surfaces

Unfoldment of non-expandable surface areas involves unfolding a system of enclosed unfoldable surfaces (within a non-expandable surface), which makes the solution of the problem approximate (there is no precise solution). When creating surfaces of this type (class) and parts from them, it is crucial to specify the unfoldment area by constructing a trial sample. Offered, accordingly, are some practical suggestions to ensure the accuracy of the unfoldings.

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The cyclone illustrated in the diagram consists of two truncated cones with the following dimensions: cone 1 – base diameters of 1600/1155 and a height of 794mm; cone 2 (composed of two parts) – base diameters of 1155/590; 590/315 with a height of 1000; 474mm. Unfoldment is achieved through the method of rolling, by deducting the surface of the smaller top-based cone from the truncated one. The unfoldings are outlined in Figure 3 a,b.

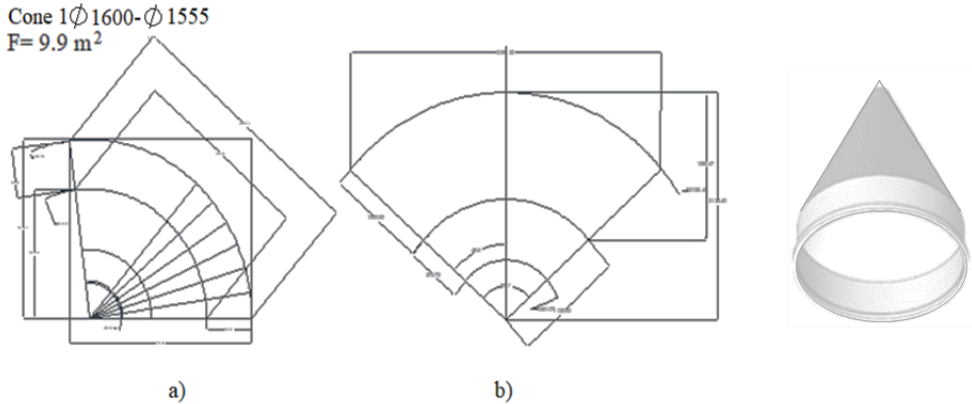


Figure 3: Expansions of cone 1 and cone 2

The sheet material measures between 1000-2000mm in width and 2000-12000mm in length, i.e. neither cone 1 ($F=9,9\text{m}^2$, outer dimensions 3332/2972mm) nor cone 2 ($F=6,8\text{m}^2$, outer dimensions 3190/2136mm) can be constructed from a single sheet of tin material. To optimize the process of cutting and reduce technological waste, minimize cut lengths through the use of plasma cutting machine, decrease the duration of cutting, etc., it is strongly suggested that the unfoldings are composed of several parts, as shown in Figure 4a (cone1), 4b (cone 2) (Tomov et al., 2019). The constituent parts relative to cone 1 and cone 2 unfoldment enable their optimal placement on the tin sheet from which they will be fabricated, as displayed in Figure 5.

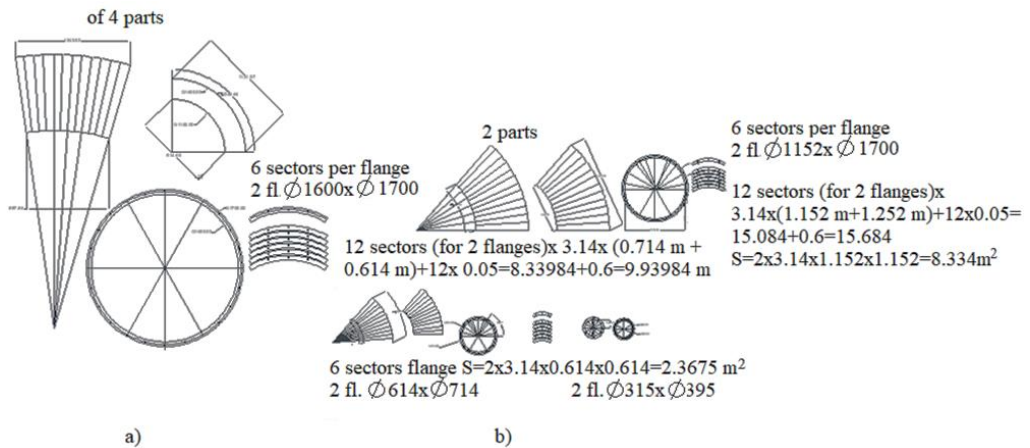


Figure 4: Composite expansions of cone 1 – a) and cone 2 – b)

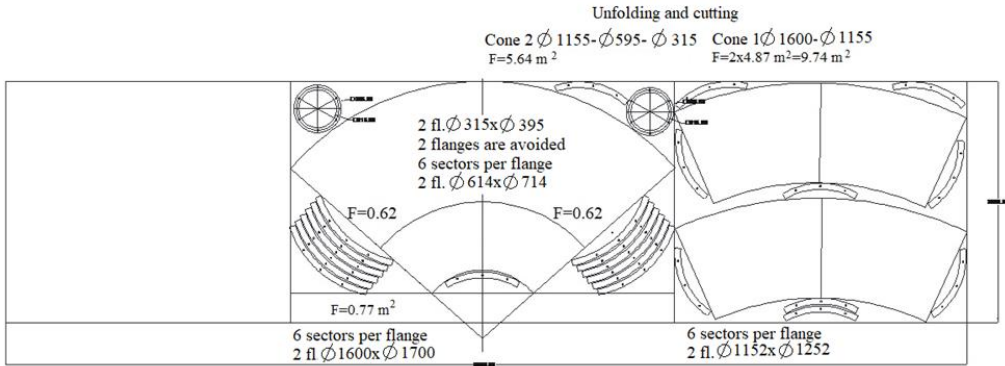


Figure 5: Unfolding and cutting of cones 1 and 2

As evident from Figure 5, the positioning of cone 2 allows for the fabrication to be completed without the need to split the two component cones, eliminating, thereby, the requirement for two flanges (12 sectors) to connect the component parts of cone 2 along the 595mm diameter surface, which, in turn, results in a usable area of $F=0,77m$. Additionally, as illustrated in Fig.6., variations in cutting the surface of cone 2 (into two component parts) can yield usable areas of $F= 0.92$ and $F= 0.94$, respectively.

RESULTS AND DISCUSSION

In some cases, even with the utilization of software, achieving the optimal cut especially for the unfoldment of non-expandable surfaces or a combination thereof, or spin-offs from all the three classes, can be challenging, and it is, therefore, imperative to evaluate the unfoldment methods in advance and decide upon those approaches, or possibly the same method that will yield favourable results. For instance, the method of meridional sections (cylindrical sections, GORE METHOD wedges, Figure 6; Figure 7), or that of the equatorial sections (polyconic sections, ZONE METHOD – Figure 8) are the ones that can be employed to efficiently unfold spherical surfaces. If the unfoldment is performed on identical element row Figure 6, or even in two rows Figure 7, then the material consumption coefficient will be significantly reduced.

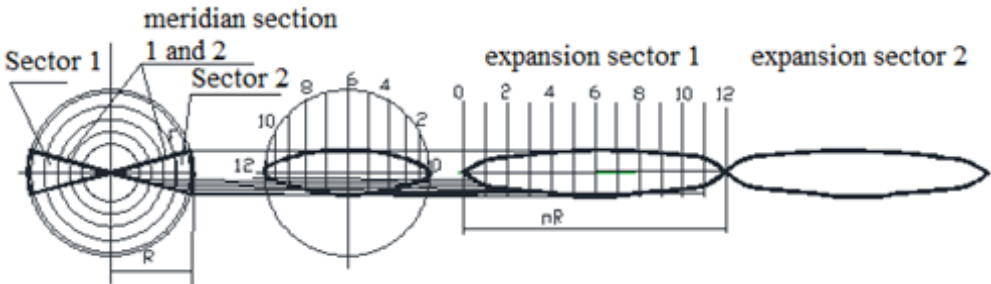


Figure 6: Expansion of a sphere by the method of meridional sections

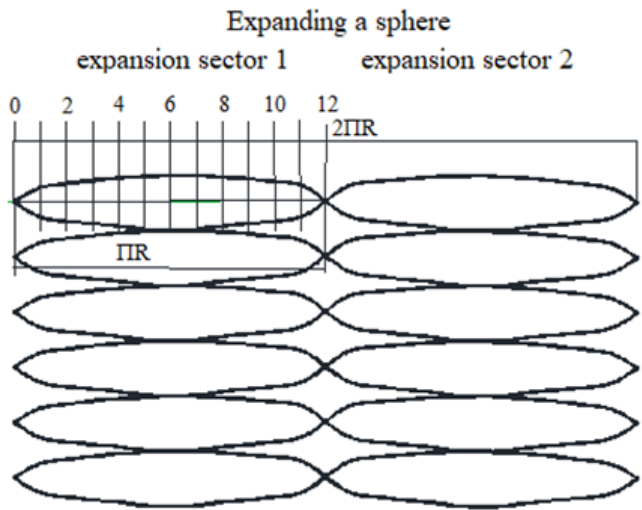


Figure 7: Full development of the surrounding surface of the sphere by the method of meridian sections

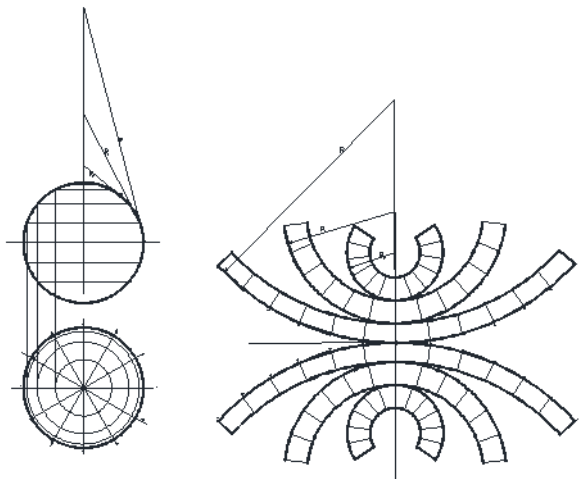


Figure 8: Expansion of the surrounding surface of a sphere by the method of parallel sections (polyconic method)

In comparison, the sheet material consumption coefficient for the same dimensions of the sphere in Figure 9a is equal to 0,634, whereas, for the optimal cut in Figure 10b it increases to 0,814.

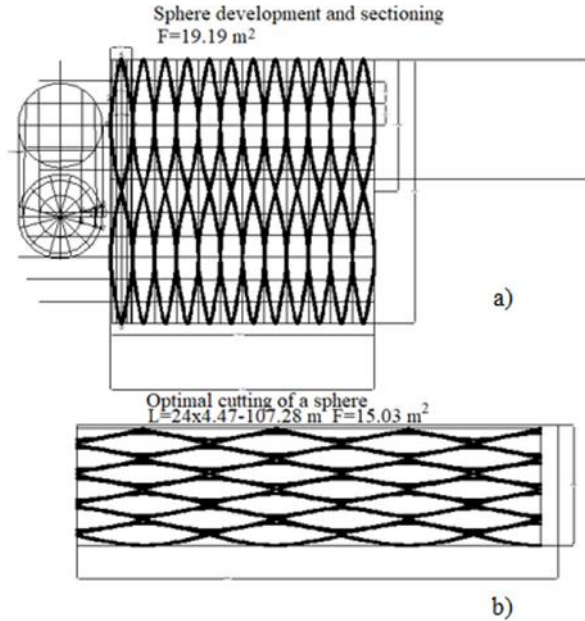


Figure 9: Optimal cutting on a non-folding surface

A more detailed analysis, the outcomes of which are presented in Figure 10, reveals that when the unfoldment is accomplished through the equatorial method (polyconic sections, ZONE METHOD Figure 8) for the cases of larger dimension parts (as is the particular case hereto discussed), optimal cuts can be obtained by decreasing the dimensions of the cut off elements and increasing their quantity in order to attain multiple sets of workpieces with identical shape and dimensions. The optimal cut layout is displayed in Figure 10b.

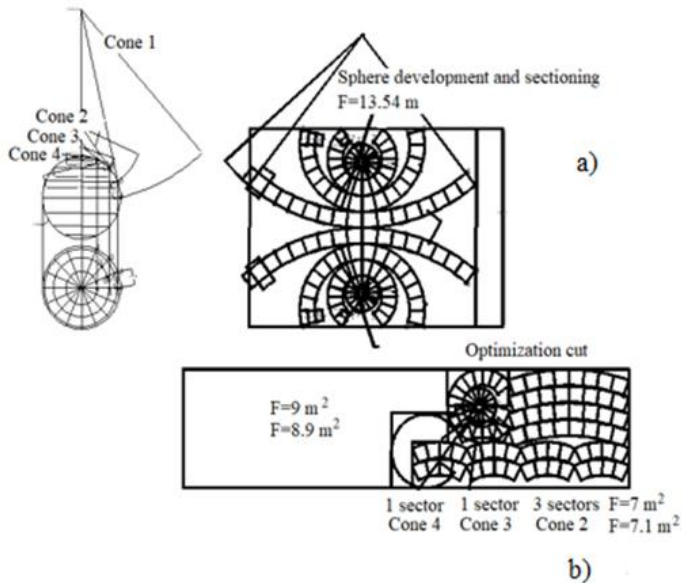


Figure 10: Optimal cutting of an inextensible surface obtained by the method of polyconic sections

CONCLUSIONS

The conclusions drawn from the analysis of the given example lead to the following recommendations:

When creating sheet material workpieces to form their surrounding surfaces, especially when they pertain to second-order rotational surfaces, it is advisable to approximate them to expandable surfaces.

As for surfaces with large dimensions, it is recommended to obtain them from multiple parts of the same shape and dimensions. Such a strategy will help minimize the amount of technological waste, shorten cut line length, reduce both auxiliary and preparation time, and lower the time required for the fabrication of the relevant parts and equipment.

Furthermore, in the case of helical design solutions, it is crucial to consider the effect of surface taper on material consumption and the process of cutting.

With reference to the conducted research, several pivotal conclusions can be reached:

AutoCAD software product is highly applicable for accurately determining the necessary quantities of sheet material required for the manufacture of machine parts with a predominant number of sheet material components, including machines used for calibration and rough cleaning of the grain, various bucket elevators– vertical and tilted type, redler conveyors, stone separators, chain conveyors with inlet hoppers, magnetic separators, cyclones, and others.

AutoCAD software is also well-suited for sheet metal cutting for the production of machine parts with a predominant number of sheet material components.

To optimize cutting, it is advisable to produce all segments (sectors) of the enclosed expandable surfaces collectively.

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