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HOW TO FACILITATE THE SELECTION OF UNIVERSAL GEAR MOTOR REDUCERS AND MEET CUSTOMER EXPECTATIONS

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Abstract: *Most manufacturers of universal geared motor reducers display only catalogs of their products on their websites, leaving customers to select the necessary reducer themselves. A very small number of leading manufacturers provide software for selecting reducers, making it much easier for customers to choose the desired reducer. Universal geared reducers, unlike special ones, are designed for transmitting mechanical energy and motion from the drive machine to the working machine for various power and speed requirements, as well as different installation forms and positions. They can be directly connected, usually with a special geared motor, or indirectly connected via adapters for standard IEC motors, belt drives, or as non-motorized versions. Due to their versatility, they are more complex to manufacture, have more components, and require greater machining to meet almost all installation requirements. Despite this, they are still cheaper in smaller series than so-called special reducers, which are designed for specific applications and lack unnecessary components or machining, and which usually cannot be adapted for other purposes. This range of offerings is shown in the manufacturers' catalogs, allowing customers to choose reducers relatively easily. However, the selection process can be further simplified with a slight increase in selection accuracy. This paper points out ways to achieve these possibilities.*
Key Words: ***selection, universal motor geared reducer***

1. INTRODUCTION

Universal geared reducers with cylindrical gears with external teeth and coaxial or nearly coaxial shafts are relatively simple mechanisms, so there is an extremely large number of manufacturers of these reducers [1], with fairly uniform quality, price, and delivery times. However, differences exist primarily in their design and range of reducers, i.e., the number of required housings, the number of different gear pairs used for making individual reducer sizes, and the number of different reducer sizes. The number of required housings within one reducer size mainly depends on the adopted reducer concept (Figure 1). There are manufacturers who focus on single-stage reducers [2], adding another single-stage to build two-stage reducers or adding a two-stage to build three-stage reducers. These manufacturers cover small transmission ratios (high speeds) and relatively small load capacities. There are also manufacturers who focus on two-stage reducers, adding single-stage to build three-stage or adding two-stage to build four-stage [3], although there are manufacturers who make single-stage separately to cover small transmission ratios. They usually cover slightly higher load capacities than the previous manufacturers. Most reducer manufacturers focus on three-stage reducers, which they build in a universal housing for two- and three-stage reducers, so by combining them, they cover the area of four-, five-, and six-stage reducers. Many of these manufacturers [4] also make single-stage reducers, practically covering a wide range of transmission ratios and high load capacities. All these solutions undoubtedly significantly affect their price and the appearance of the reducers.

The selection of the concept depends on the segment of the market the manufacturer wants to cover, that is, the specific market requirements. Regardless of the adopted concept, almost all manufacturers produce reducers for standard installation types: with feet, with feet and a small flange, with a small flange, with a medium flange, with a large flange, with a mixer flange, with common installation positions (from M1 to M6), with a direct connection of the reducer to a special reducer electric motor, with an indirect connection of the reducer with an adapter for IEC motors (where the reducer can be supplied without or with a standard IEC motor), with an indirect connection via a belt drive, where the reducer can be supplied with or without a standard IEC motor and with a classic input, as a non-motorized reducer, where the reducer is supplied without a motor. In addition to these requirements, motor reducers allow the selection of the position of the terminal box on the electric motor as well as the position of the cable entry on the motor terminal box. Today, in many cases, electric motors are supplied with certain electronics that ensure soft start or speed regulation, etc. In the case that the reducer operates continuously in elevated ambient temperatures (for gear reducers, this is usually above 60°C), it is necessary to provide systems for cooling the oil in the reducer. In the case that the reducer operates in extremely low temperatures (below -30°C), the required service factor needs to be increased by 20% [4]. Of course, in some cases, it is required that the reducer operates in an explosive environment, and then special reducers (with Ex protection) are supplied, which are produced by very few manufacturers because such reducers are very rarely demanded.

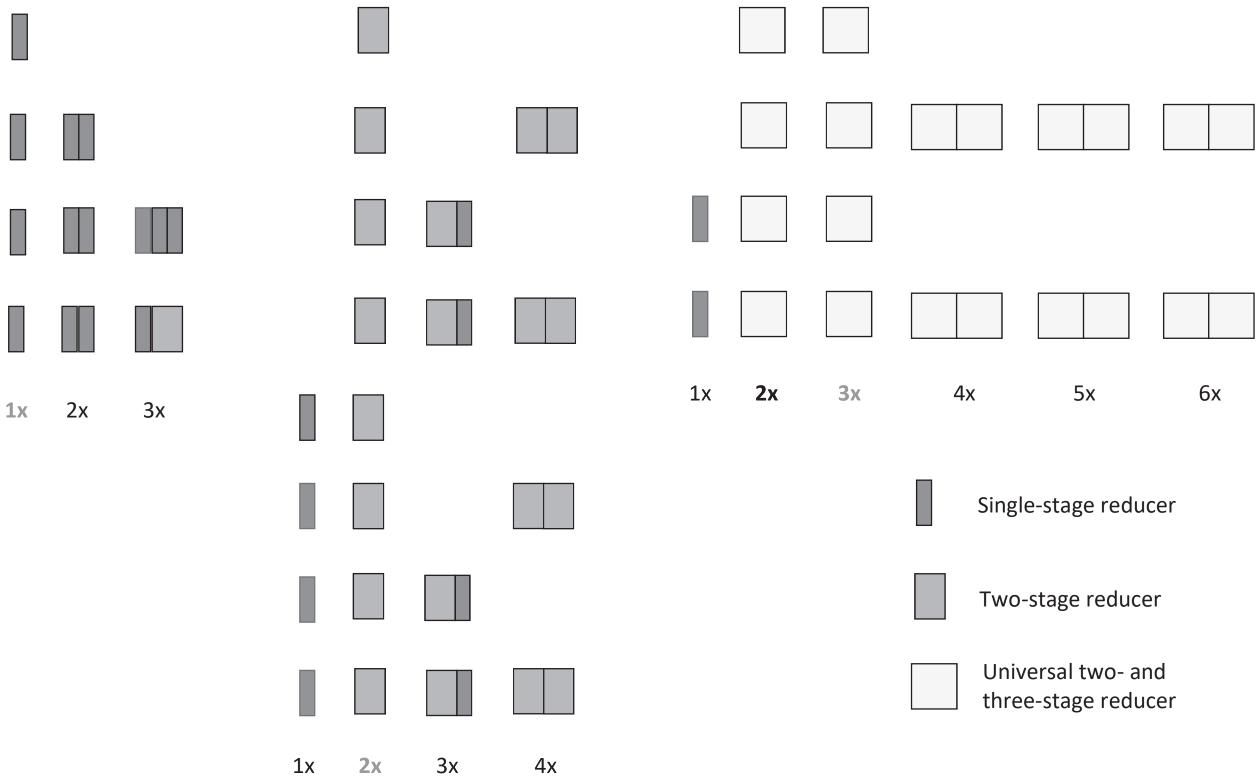

Fig. 1. *Characteristic conceptual solutions of universal gear motor reducers with cylindrical gears with external teeth*

2. PROBLEM DESCRIPTION

In most cases, when a customer opens a catalog, they have practically already chosen the type of reducer. In this case, it is a gear reducer with cylindrical gears featuring external teeth and coaxial or nearly coaxial shafts, which operates under normal working conditions. They have also decided in advance whether they need a motorized or, possibly, a non-motorized reducer. Generally, the customer usually opts for a motorized reducer, especially when it comes to small and medium-sized reducers where the reducer housing can support the electric motor. This is because, with motorized reducers, there is no need to separately mount the electric motor, align the axis of the electric motor shaft with the input shaft of the non-motorized reducer, or use a coupling to connect the motor and the reducer.

The selection or customization of gear motor reducers is very simple. Based on the required motor power and the required output shaft speed of the reducer, the size of the reducer is chosen from the catalog according to the necessary service factor value, which is determined based on the load severity. The customer determines the load severity based on the manufacturer's recommendation, which categorizes individual machines by load severity (light with a coefficient $k \leq 0.2$, medium with a coefficient $k \leq 3$, and heavy with a coefficient $k \leq 10$), the operating duration per day in hours, and the number of reducer starts per hour. A reducer with the same or higher service factor value than required is always chosen.

In some cases, the exact load severity cannot be determined, so it is necessary to calculate the inertia moment of the rotating parts of the working machine and determine the value of the coefficient k (where $k = J_{Lx}/J_{Mot}$, with J_{Lx} being the inertia moment of the working machine rotor reduced to the electric motor shaft and J_{Mot} being the inertia moment of the electric motor rotor [4]), based on which the load severity is determined. If it exceeds 10, it is necessary to consult the manufacturer for the reducer selection. By developing appropriate software, the necessary drive factor value could be immediately determined, and the reducer selected.

Namely, when the value of the coefficient k is greater than 10, the service factor value is greater than 2, and in such cases, the required reducer cannot be selected from the catalog because it only displays reducers covering service factors up to $f_B = 2$ (Fig. 2). If a reducer with a service factor value of $f_B = 2$ exists for the given power and speed, stronger (larger) reducers are not displayed to simplify the catalog. However, it follows that it is sometimes necessary to display stronger reducers to select the required reducer for heavier loads or the presence of larger radial and/or axial forces without special consultation with the manufacturer.

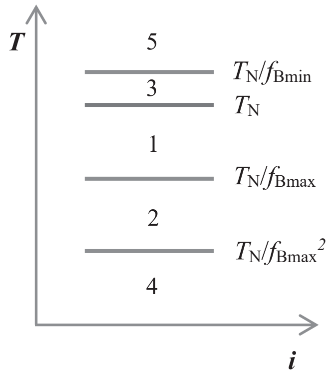

Fig. 2. *Characteristic areas of reducer application: 1 - Basic area of reducer application, 2 - Supplementary area of reducer application, 3 - Area of application for short-term drives, 4 - Area where the reducer is oversized, 5 - Critical area of application, where immediate reducer failure occurs (f_{Bmin} = 0.8 - the minimum drive factor value that allows short-term drives to overload the reducer up to 1.25 T_N, f_{Bmax} = 2 - the maximum drive factor value under normal operating conditions)*

When the size of the reducer is selected, it is checked whether the reducer's output shaft is subjected to radial and/or axial forces. If it is subjected to such forces, it is then checked whether the output shaft of the selected reducer can transmit those forces. If it cannot, a larger reducer needs to be chosen. If a larger reducer is not listed in the catalog for the given power and speed, the customer is forced to contact the manufacturer to select a larger reducer. By developing appropriate software, a larger reducer could be immediately recommended to the customer (if such a solution exists) without the need to communicate with the manufacturer.

It is important to emphasize that manufacturers specify in their catalogs the maximum radial and axial force on the output shaft that the reducer can transmit in the most unfavorable case. By developing a relatively simple program that takes into account the angle at which the radial force acts along with the possible action of the axial force, it could be ensured to calculate the actual allowable value of the radial force, which in some cases could avoid the need to choose a larger (more expensive) reducer.

The calculation of the allowable radial and axial load on the reducer's output shaft is performed based on the strength (durability) of the shaft, the bearing capacity, and the load capacity of the key. The bearing calculation usually ensures that the bearings provide a working life of at least 10,000 hours, i.e., a usability life of 5 years (5 years x 50 working weeks x 40 working hours per single shift = 10,000 hours).

When a reducer is selected, the customer chooses one of the following solutions: a gear motor reducer with a direct connection to a typically special reducer electric motor (with or without a brake), an indirect connection with an adapter for standard IEC motors, where the reducer can be supplied with or without a motor, or an indirect connection via a belt drive, where the reducer can again be supplied with or without an electric motor. In the case of a non-motorized delivery, the transmission ratio of the belt drive must also be considered. In some cases, customers prefer reducers with standard IEC motors so that in the event of a motor failure, the damaged motor can be replaced more quickly, as delays caused by the replacement of special reducer electric motors can last longer and cause significant losses for the customers. Additionally, in the case of exporting reducers to countries that have their own electric motor factories protected by high tariffs, it is much more favorable to export reducers without electric motors.

When the size of the reducer is defined, the installation type must be specified, as well as the installation position (from M1 to M6), to correctly arrange the openings for oil filling, level checking, and draining, as well as the breather openings. In the case of delivery with a motor, the position of the terminal box and the position of the cable entry on the terminal box must be defined. If a soft start is required, which is often used in heavier operating conditions (since four-pole asynchronous electric motors, commonly used for drives, are characterized by a sudden start with a starting torque about twice the nominal, causing large shocks), the type of electronics must be specified. When regulated drives are used, as the actual speeds can sometimes differ by up to 5% from the values defined in the catalog and depend on the load severity, this must be specifically indicated. Additionally, if a change in the output shaft speed is required for technological reasons, usually within a range of 1:10, this must be highlighted. If a special color for the gear motor reducer is desired, this must also be specified, as many manufacturers can fulfill this requirement. The factory color for reducers is most commonly chosen from various shades of blue, gray, black, green, and red. Of course, at the customer's special request, reducers can be painted in a different color, but this affects the price of the reducer. Therefore, customers generally accept the manufacturer's color and later, if necessary, paint the reducers in their own color to match the machine or installation in which the reducer is installed.

If a non-motorized reducer is chosen, the calculated torque value is multiplied by the required drive factor value, and the reducer is selected from the manufacturer's catalog for the required transmission ratio, with a nominal torque greater than or equal to the required value. The other selection procedures are the same as for motorized reducers, except there is no need to define the characteristics of the electric motor. The characteristics of the electric motor are defined separately when ordering the motor.

3. PROBLEM SOLUTION

By developing relatively simple software, the process of selecting (personalizing) a geared motor can be automated, defining its complete designation and providing its drawing with all necessary dimensions. Today, leading manufacturers of gear motors mainly have such applications [5, 6, 7, 8, and 9], and customers use them successfully. However, with most of these applications, it is necessary to separately determine the value of the drive factor, and these programs do not consider the effect of external forces on the free end of the shaft. Moreover, most do not provide a complete drawing with dimensions, which can be considered the main drawback of these programs. The modified application would eliminate all these issues. Additionally, an application (configurator) could be developed to initially select the required type of gear motor, posing questions such as whether there is enough axial space for installing the gear motor. If there is, the choice would fall on spur gear motors with external gear teeth as they are the cheapest. Then, whether there is enough radial space; if so, a spur gear motor would again be chosen. It would also inquire whether there are specific noise level requirements; if there aren't, a spur gear motor would be chosen again. Whether self-braking is required; if not, a spur gear motor would be chosen (although some spur gear motors can be supplied with a one-way clutch brake or a brake motor, and not all worm gear motors are self-braking either). Of course, in spatially constrained conditions, gear motors with an intermediate connection between the motor and gear motor with a belt drive can be supplied, although these solutions are used in cases where motor slip is needed in case of overload. For different requirements, the recommended software would suggest another type of gear motor.

When selecting helical gear reducers with cylindrical gears with external teeth and coaxial or nearly coaxial shafts, the first question would be whether to choose a motorized or non-motorized reducer. It should be emphasized that non-motorized reducers are exceptionally rarely requested for small and medium sizes of reducers.

If the choice is for motorized reducers, it is necessary to define:

- Motor power,
- Required number of revolutions of the reducer's output shaft,
- Drive weight (light, medium, heavy) and possibly the moment of inertia of the working machine's rotor,
- Duration of operation during the day in hours,
- Number of reducer engagements per hour,
- Ambient temperature in which the reducer is to operate (if it is above 60°C), because helical reducers operate with high efficiency (about 0.98 per gear pair), resulting in very low losses and no excessive heating of the reducer under normal operating conditions, thus eliminating the need for additional oil cooling in the reducer.
- Mounting form,
- Mounting position,
- Method of connection between motor and reducer,
- Size and location of the radial force if it acts on the reducer's output shaft, and its cause,
- Size and direction of the axial force if it acts on the reducer's output shaft,
- Desired mounting form,
- Desired mounting position,
- Desired connector position,
- Desired inlet position, and, possibly,
- Desired color of the reducer if a different color from the usual factory color is preferred.

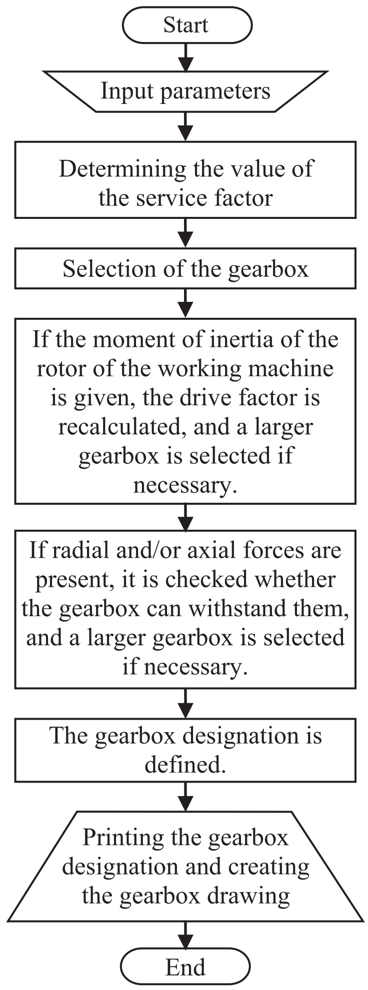

Fig. 3. *A rough algorithm for selecting a helical gear reducer with cylindrical gears*

If the choice falls on non-motorized reducers, it is necessary to define:

- Torque on the input shaft of the working machine,
- Required transmission ratio of the reducer, which is calculated based on the number of revolutions of the reducer's output shaft and the number of revolutions of the electric motor (usually a four-pole asynchronous motor with an asynchronous speed slightly above 1400 min-1),
- Drive weight (light, medium, heavy) and possibly the moment of inertia of the working machine's rotor,
- Duration of operation during the day in hours,
- Number of reducer engagements per hour,
- Ambient temperature in which the reducer is to operate, if it is above 60°C,
- Mounting form,
- Mounting position,
- Size and location of the radial force if it acts on the reducer's output shaft, and its cause,
- Size and direction of the axial force if it acts on the reducer's output shaft,
- Size and location of the radial force if it acts on the reducer's input shaft, and its cause,
- Size and direction of the axial force if it acts on the reducer's input shaft,
- Desired mounting form,

- Desired mounting position, and possibly
- Desired color of the reducer if a different color from the usual factory color is preferred.

Based on the provided data, the reducer is selected (personalized) according to the program shown in Fig.3, and its designation is defined to facilitate its order, and a drawing of the selected motorized or non-motorized reducer is provided.

3.1. Examples of working with applications for configuring mechanical transmissions (configurators)

Based on the insights into the operation of mechanical transmission configurators from leading global manufacturers (SEW [5], Nord [6], Rossi [7]), it can be concluded that they all adhere to the rough algorithm of the application shown in Figure 3. The main differences in working with them are their appeal, accessibility, and ease of use.

Comparing the configurators of these three gearbox manufacturers, it can be concluded that SEW offers the best user accessibility as it provides various images within the options to make the offered choices as clear as possible. The images are in color with different details, which significantly enhances working with the configurator (Figure 4).

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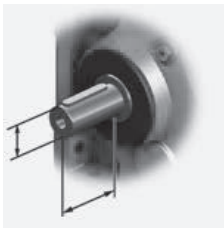

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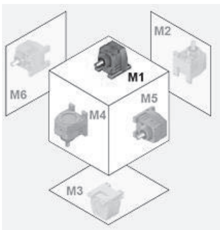

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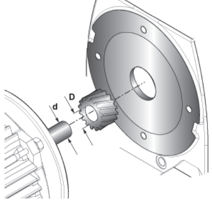

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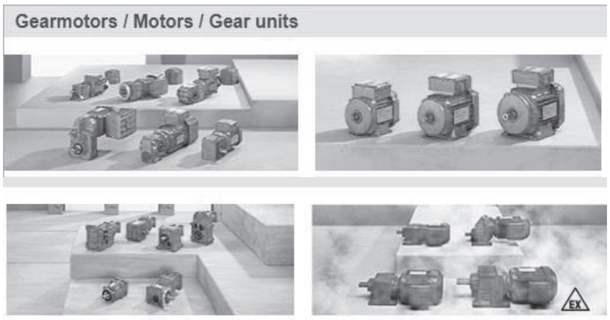
Fig. 4. *Configurator assistance in the form of images and detailed explanations of possible mechanical transmission options (a - transmission type and mounting method, b - flange dimensions, c - output shaft dimensions, d - mounting position, e - housing color, f - shaft and drive gear diameter)*



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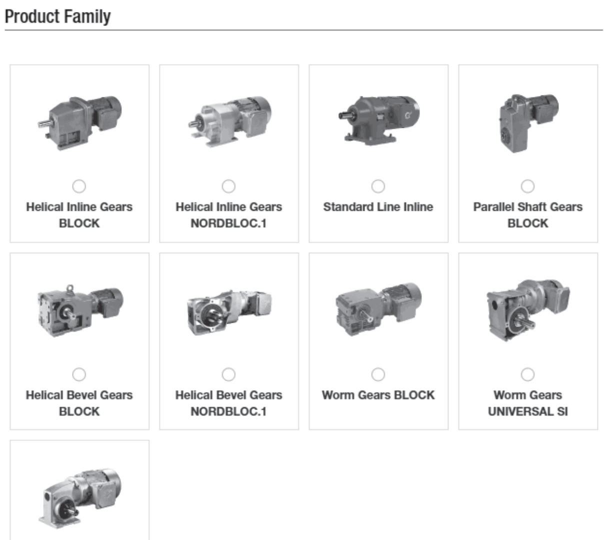

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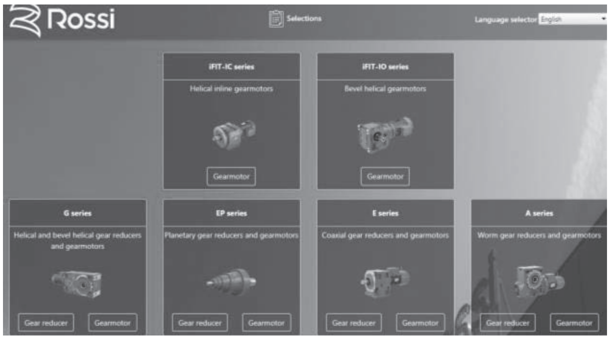

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Fig. 5. *Initial question for selecting the mechanical transmission to be configured (a - SEW, b - Nord, c - Rossi)*

Ease of use is ensured by the sub-phases of configuration, which further simplify the configuration of the entire transmission. SEW offers this in four sub-phases (general data - variants - options - review of the obtained solution). Rossi offers something similar with its five sub-phases of configuration (general data - design - additional options - motor - review of the obtained solution). The Nord transmission configurator offers all this on just one page, making the overall product presentation more complicated and harder to understand. This "user-friendly" method can be further improved in the future with more complex applications that contain even more graphical or, better yet, animated displays, where selection can be made directly through the image, rather than by circling the offered methods.

It should be noted that at the beginning, all configurators have a question displayed alongside an image regarding the type of mechanical transmission being configured (cylindrical coaxial, cylindrical parallel, conical, cylindrical-conical, worm gearboxes) (Figure 5). At the end of the application, all configurators offer a review of the configured mechanical transmission, with SEW offering the most options for drawings and details, Nord offering a separate drawing and a separate PDF report, while Rossi provides a longer PDF report with all the data including dimensions and mounting images.

The accessibility of using mechanical transmission configuration applications can greatly attract new customers, primarily those who have not previously purchased mechanical transmissions or have purchased them from companies that did not offer a configuration application. However, customers who have long been using transmissions from a certain company will find it harder to decide to change, as they are accustomed to existing gearboxes and already know in advance which gearbox they will use.

4. CONCLUSION

Based on the conducted analysis, it follows that by developing a relatively simple software, slightly more complex than the software currently used by leading reducer manufacturers, it would be possible to perform an even simpler selection of reducers, i.e., their personalization with the possibility of directly determining the necessary drive factor value. The possibility of directly determining the drive factor would be particularly interesting when there is a large moment of inertia in the working machine rotor.

The greatest advantage of the proposed solution would be in its ability to consider the load-bearing capacity of external radial and/or axial forces that may act on the reducer's output shaft and select a reducer capable of withstanding those forces. Although such load cases are rare, reducer manufacturers should pay more attention to them. Considering all these elements would significantly simplify the definition of the reducer's designation and the creation of drawings with all dimensions, which would be the main advantage of the proposed software solution.

Of course, all this data about the reducer is also present in current catalogs, but it is necessary to consider the position of the motor reducer, the position of the connector and inlet, as well as the dimensions depending on the chosen motor size.

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