GENERAL DESCRIPTION OF ENGINEERING SERVICES

offered and performed by *Laschet Consulting GmbH*

Vers. 1.2 / 01.10.2023

In the **OFFER (QUOTATION)** or in the **CONFIRMATION OF ORDER (ACKNOWLEDGEMENT)** of *Laschet Consulting GmbH* (hereinafter referred to as "LC") **Engineering Services** are listed, which can be described in general terms as follows:

1.
Calculation of Torsional Vibrations in Drive Systems (TVA = Torsional Vibration Analysis)

These calculations are performed by LC with the aid of simulation software. In the first step, it is necessary to create a corresponding discrete computer model of the drive system.

For the purpose of generating such a model LC receives suitable **specification information** (data, technical drawings) from the client, which are summarized in the following list. The provision of this information is at the expense of the client. LC does not carry out any design work (i.e. preparation of technical drawings) or measurements within the scope of these engineering services.

Compilation of the necessary specification information (provided by the client):

- general information and overview information of the complete drive structure, e.g. on the basis of **sketches/pictures/photos**, **catalog information**, **publications**, **technical descriptions** from manuals or operating instructions, **functional descriptions**

- all geometries (lengths, inner/outer diameters, contours) of the inertia-related rotating elements for the purpose of determining the **mass moments of inertia [kgm²]**; *alternatively (or additionally):* direct specification of the numerical values in SI units [kgm²].

- all geometries (lengths, inner/outer diameters, contours) of the stiffness-related rotational elements for the purpose of determining the **torsional stiffnesses [Nm/rad]**; *alternatively (or additionally):* direct specification of the numerical values in SI units [Nm/rad].

- specification of characteristic curves (if required) such as coupling characteristics (torque-angle characteristics) as well as further details on special drive elements (such as slipping / overload / shifting clutches, torque measuring shafts, cardan shafts, gear stages); if available: also specification of damping values (e.g. the known PSI values of flexible couplings with rubber elements)

- in the case of drive systems with gearboxes: gearbox data such as number of teeth, tooth width, helix angle, pitch circle diameter, if applicable tooth clearances (backlash) as total angle, if available: tooth stiffnesses

- depending on the scope of the order: excitation torques and load functions, i.e. all **excitation or load torques [Nm]** of electric motors, combustion engines, machines (e.g. compressors, pumps), other time/speed-dependent process events, etc. in dependence of the operating behavior (specification in the form of tables, data sheets, characteristic diagrams, preferably in Excel-compatible files); more detailed description of the operating conditions (i.e. initial conditions for the simulation; min./max. speeds); details of these data always in consultation with LC

- if available: measurement data for the purpose of model matching

- if necessary, combination of parameter variations and/or parameter ranges, if variation studies are part of the order

Results of torsional vibration calculations usually include the **determination of natural frequencies (critical speeds), mode shapes including the evaluation of excitability using CAMPBELL diagrams** and, in the context of simulations in the frequency and/or time domain, also the **torque responses** at specific stations/elements of the drive system as a function of a given excitation.

For further details regarding this scope of services please refer to the **OFFER (QUOTATION)** or the **ORDER CONFIRMATION (ACKNOWLEDGEMENT)**.

2.
Calculation of Lateral (Flexural) Vibrations in Drive Systems

These calculations, which may also be part of a higher-level rotordynamic analysis, are performed by LC with the aid of appropriate rotordynamic simulation software. Depending on the task, LC may also coordinate this service with the US company RBTS, Inc. LC acts as cooperation partner, representative and representer of RBTS, Inc. in Europe. As a rule, such services, which are partly or completely carried out together with RBTS, Inc., are also invoiced via LC.

For the purpose of generating such a model, LC shall receive from the client suitable **specification information** (data, technical drawings), which is already summarized in the list under 1. The provision of this information shall be at the expense of the client. LC does not carry out any design work (i.e. preparation of technical drawings) or measurements within the scope of these engineering services.

In addition to 1. the following specification information is required by the client:

- information on the installed shaft bearings (ball/roller bearings or slide/fluid-film bearings); here in particular details on the exact installation position, the bearing design and the **radial bearing stiffnesses [N/mm]**; if necessary, also specification of a characteristic diagram or value ranges for bearing stiffnesses (for the purpose of estimating this parameter influence on natural frequencies)

- imbalances in the installed rotating elements (especially with the larger masses/inertias)

- exact specification of the speed operating range (min./max. speeds)

- Extended rotor dynamics analyses in connection with fluid-film bearings require additional specifications which must be discussed in detail before the contract is awarded. For this purpose further details are also required in consultation with the cooperation partner RBTS.

- if necessary, combination of parameter variations and/or parameter ranges, if variation studies are part of the order

Results of the lateral/flexural vibration calculations usually include the determination of **natural frequencies (critical speeds), mode shapes including the evaluation of the excitability by means of resonance diagrams** as well as, within the scope of simulations in the frequency and/or time domain, the **torque responses/displacements** at special stations/elements of the drive system depending on a given excitation. In addition, the **bearing loads** are specified. For further details regarding this scope of services please refer to the **OFFER (QUOTATION)** or the **ORDER CONFIRMATION (ACKNOWLEDGEMENT)**.

3.
GENERAL NOTES

LC points out in this context that the good quality of the specification information regarding the accuracy and practical relevance of the computational investigations is a crucial condition. On the basis of the specifications, the calculation model is created, which can only correspond best to reality if these specifications are consistent. LC can check the supplied specification information for plausibility if necessary; a further detailed check of this information for correctness, completeness and practical relevance for the task at hand is the sole responsibility of the client.

As part of the engineering services LC delivers a technical report in either English or German language. This report is delivered digitally as a PDF document.

Further explanations, consultations or additional analyses (investigations, parameter studies) are carried out according to the explicit task of these additional services. Possible expenses for travel costs (plus incidental costs, expenses) will be invoiced separately.

As LC does not carry out any measurements within the scope of the engineering services provided, it is strongly recommended to compare and verify the delivered technical calculations by means of representative and comparable measurements. If necessary, the client should consult an external service provider (specialist) for this purpose. As part of this coordination work, LC could also offer additional consulting services or supplementary model adjustment (refinement) and calculation studies.

It is a matter of course for LC that project-related and previously unpublished data and information provided by the client is subject to confidentiality. Upon request, a separate confidentiality (non-disclosure) agreement (NDA) can be concluded, which, depending on the subject matter of the order, also refers to the LC cooperation partner RBTS, Inc. (USA).

In addition to telephone contact and the exchange of information via E-mail, meetings, consultations and presentations in the context of online meetings (Cisco Webex) are also referred to as suitable communication channels.

LC has a Webex license and can invite participants worldwide as a host to a joint online meeting (online video/audio conference) of any duration. Apart from the usual (telephone and) Internet costs, there are no additional costs for the participants. Depending on the type and duration of such online meetings, the associated order-related service costs could be invoiced as additional expenses; as a rule, these expenses are included in the engineering order.

On request, customers can also invite to online meetings via the customer's own platform (e.g. via Microsoft Teams, Zoom, Google Meet).