LIFE E-VIA

"Electric Vehicle noIse control by Assessment and optimisation of tyre/road interaction"

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List of keywords and abbreviations

CAE	Computer-Aided Engineering
CRS	Constant Rolling Speed
EV	Electric Vehicle
FEM	Finite Element Model
HPC	High Performance Computing
ICEV	Internal Combustion Engine Vehicle
OE	Original Equipment
OEM	Original Equipment Manufacturer
RFQ	Request For Quotation
SPL	Sound Pressure Level
TA	Target Approval
UNECE	United Nations Economic Commission for Europe

Table of contents

1 Introduction

Within LIFE E-VIA action B7 [1] a reduction of tyre/road noise of up to 1.0 dB(A) was accomplished for an electric vehicle (EV) tyre operating under urban conditions. This reduction was relatively robust for different vehicles, road surfaces, or operating conditions, thus proving the overall robustness of the implemented solutions. The very good noise performance of the LIFE E-VIA tyre was combined with a very balanced and competitive portfolio of non-noise related performances. For the investigated criteria the already very good performance levels of the reference Continental EcoContact 6 tyre could be maintained or even slightly improved. Concluding, it can be stated that action B7 was successful in implementing a sustainable, holistic low noise optimized EV tyre for urban applications.

These results were not obtained by developing new technical solutions, instead existing, validated technologies were combined in smart and novel ways. The long-term value of action B7 in this regard is related to the new or adapted processes which allowed to optimize the combined performance of the used technologies.

Additionally, a fundamental knowledge increase was obtained by a series of investigations on the influence of measurement conditions on accelerated pass-bys. Action B7 was able to close some important knowledge gaps at least partially. This additional insight into how accelerated pass-by noise testing data can be used to enhance the tyre development process was an important enabler for the goal-oriented noise and target conflict optimisations within action B7. Additional important insights were gained into the requirements for assuring that this accelerated pass-by test data is obtained in a coherent way.

Within this deliverable for action E2 it will be analysed how these outcomes of action B7 can be exploited for future tyre development activities. This analysis starts with a short assessment of the market relevance of the outcome of the LIFE E-VIA action B7. This assessment is presented in Section 2. The following Section 3 forms the major part of this document. It contains the exploitation plan which investigates how the insights from and on accelerated pass-by noise testing, and the adaptations to the tyre development process could potentially be used within tyre development projects. This report concludes with a summary of the findings which is given in Section 4.

2 Market relevance of the LIFE E-VIA action B7 outcome

There are two different business models for selling tyres. One is the so-called *Replacement* market where tyres are sold directly to the end consumer buying replacement tyres for their vehicles, and the other the *Original Equipment* (OE) market where tyres are sold as original equipment to vehicle manufacturers.

Due to the different customers, there are differences in how the market potential of a holistic low noise optimised EV tyre like the one which was developed in LIFE E-VIA action B7 can be assessed. The replacement market is very heterogeneous. The individual customer might make a buying decision based on magazine or internet test results, price, EU tyre label [2] values, expected lifetime, brand recognition, marketing, dealer recommendation, etc. Which factors are deciding is different for every customer. It is thus difficult to assess how much of an active part low exterior noise performance plays for the buying decision of the individual customer.

For the OE market this assessment is easier. OE business always starts with *request for quotation* (RFQ) from the vehicle manufacturer to the tyre company. This RFQ will also state the expected pass-by noise performance of the tyre. Traditionally, it was often requested that this noise performance is measured in accordance with UNECE R117 [3]. However, since the revision of the vehicle noise homologation regulations UNECE R51.03 [4], and with the advent of EVs, many vehicle manufacturers have changed the conditions under which pass-by noise levels for the RFQ should be measured. UNECE R51.03 comprises a set of different pass-by measurements at 50 km/h with and without acceleration from which a combined urban sound pressure level is calculated. Nowadays most vehicle manufacturers either request tyre pass-by noise to be measured with an electrical test vehicle in accordance with R51.03, or they prescribe their own proprietary pass-by noise measurement methodologies. Nearly exclusively these will involve noise testing at 50 km/h and will include accelerated pass-bys.

Both R51.03 pass-by noise testing with EVs and the typical proprietary pass-by noise testing prescribed by some OE customers are very similar to the pass-by noise tests which were done as part of the tyre development in action B7. As such it is reasonable to assume that the improved tyre exterior noise performance which is shown in Table 13 in [1] can be directly translated to an improved noise performance in the so-called *target approval* (TA), in which the compliance with the RFQ performance requirements is approved by the OEM.

In addition to the changes in the requested tyre pass-by noise test procedures in the RFQ, also the pass-by noise levels themselves which the vehicle manufacturers require have changed in recent time. The requested sound pressure levels have tightened and being able to report lower pass-by sound pressure levels can be a business advantage compared to competition. In view of this it makes sense that an assessment of the market relevance of the outcome of LIFE E-VIA action B7 should focus on the OE market. With better procedures for quality assurance for accelerated pass-by noise testing and performance prediction during development – both outcomes of action B7 – there is the business potential to be successful in additional TAs.

3 Exploitation plan

Within LIFE E-VIA action B7 a pass-by noise reduction under urban conditions of up to 1.0 dB(A) was accomplished. The achieved noise performance was relatively robust to variations in operating conditions such as vehicle, operating conditions, or road surface. The very good noise performance of the LIFE E-VIA tyre was combined with a very balanced and competitive portfolio of non-noise related performances. In view of this, the final LIFE E-VIA tyre fulfilled the planned outcome of action B7.

These results were not obtained by developing new technical solutions, instead existing, validated technologies were combined in novel ways. The long-term value of action B7 is thus related to the new or adapted processes which were created to optimise noise in a holistic way for EV applications. This is one of the two major outcomes of action B7 which is worth exploiting from a tyre development point of view. Moreover, a fundamental gain in knowledge was achieved from a series of investigations on the influence of measurement conditions on accelerated pass-bys. Action B7 was able to close some important knowledge gaps in this regard. This additional insight into accelerated pass-by noise testing, and how the resulting measurement data should be analysed, was an important enabler for the noise optimisations which could be done in action B7.

Potential ways for the future use of the outcome of action B7 are described in the following sections. Section 3.1 explains why none of the technological solutions which were used for the tyre optimisation in action B7 can be directly exploited when used in an isolated way (i.e. neglecting the interaction with all other tyre features). The steps which are necessary to properly utilise the understanding of accelerated pass-by noise testing and its relevance for EV tyre optimisation in an urban context are described in Section 3.2. Possible adaptations to the tyre development process which are motivated by the findings of action B7 are described in Section 3.3.

3.1 Technologies

In action B7 the holistic noise optimisation of the EV tyre was achieved using technical adaption of the Continental EcoContact 6 reference tyre. None of these adaptations was a novel technological solution. The optimized, holistic noise performance which was achieved in LIFE E-VIA action B7 was thus not a consequence of a new technological solution, it was instead achieved by using novel development approaches and new insights from accelerated pass-by noise measurements to optimise the interaction of these existing technologies in a target-oriented way. Within the context of this exploitation plan it is thus not useful to investigate exploitation options for the used technologies as these are already well established.

3.2 Tyre testing

As was shown in LIFE E-VIA preparatory action A3 [5], noise under acceleration is of greater importance for EVs compared to internal combustion engine vehicles (ICEV), especially in urban environments. This directly implies that exterior tyre/road noise testing under acceleration is more important than ever. However, while CPB measurements at constant speed have been used for decades, and thus are well understood, the procedures for accelerated pass-by measurements are still quite new. This means that there is limited knowledge on how these types of measurements are affected by variations in test conditions, test vehicle, etc. In order to close this gap at least partially, action B7 included an analysis on how accelerated pass-by tests are affected by the conditions which are prevailing when testing is done.

A large part of the exterior noise reductions which were achieved in LIFE E-VIA action B7 were a direct consequence from the fundamental gain in knowledge which was achieved from the aforementioned investigations. Only the proper evaluation and understanding of test results, and their limitations, allowed for a target-oriented tyre optimisation. During these investigations it was found that it is not possible to consider tyre and vehicle independent of each other. In contrast, they need to be treated as a combined system for accelerated pass-by measurement purposes. Furthermore, a strong influence of the ambient air temperature on the noise increase under torque (the *torque effect*) was also reported in B7. The consequences which these vehicle and temperature influences have for test planning, execution and data analysis will be discussed in the next sections.

As the noise optimisation part of the tyre development is still highly dependent on measurements, these findings are highly relevant. On the one hand, within the development process it needs to be assured that the right type of testing under the right conditions is used to guarantee that results from accelerated noise tests are both relevant to the development goals, and are comparable between different development phases. On the other hand, the large influence of operating conditions on the sound pressure level (SPL) under torque is not limited to testing only. The same variations will be observed under real life driving. Thus, the development process needs to guarantee that a robust reduction of tyre/road noise can be achieved under the diverse traffic and operating conditions which are encountered for driving in urban environments. For this a good understanding of how accelerated pass-by noise is affected by operating conditions is of vital importance.

3.2.1 Test vehicle selection

One of the findings of the accelerated pass-by measurement study in action B7 was the influence of the test vehicle on the test results. Relative differences between tyres varied by up to 1 dB(A) between accelerated pass-by tests which were conducted using two different but comparable test vehicles from the same market segment. This finding needs to be integrated into the test planning for accelerated pass-by measurements. The management of the test vehicles which are used for these measurements is affected by the conclusions from action B7 in three different ways:

1. Some tire sizes can be mounted on more than one of the test vehicles. For comparable results, e.g. in different loops of one tire line development, test planning needs to assure that always the same vehicle is used for these tests.
2. Testing can be performed at more than one proving ground, e.g. to mitigate the impact of meteorological conditions on testing. With respect to the test vehicle fleet identical conditions between these proving grounds must be assured as much as possible. In the past potential test vehicle differences between different test locations have been of minor concern for CRS (constant rolling speed) pass-by noise measurements. As was shown by action B7 the same might not be true with respect to accelerated pass-by tests. If identical test vehicle fleets cannot be assured, potentially test location specific vehicle correction factors need to be determined.
3. In case of vehicle temporary downtimes, e.g. for service, replacement vehicles need to be of the same model as the original test vehicle. If this cannot be assured, the replacement vehicle can only be used for accelerated pass-by measurements where it is known that there is no need for results to be compared with other tests which have been done in the past or which will be done in the future.

3.2.2 Environmental conditions

In Section 3.2.3.1 in the B7 report [1] test data from two accelerated pass-by noise tests is discussed. These two tests have been performed for the same set of tyres under absolutely identical conditions apart from the ambient temperatures. One test has been performed in the morning hours at ca. 16 °C air temperature, the other midday at 35 °C. The measured torque effect changes by 1.1 dB(A), with the higher observed effect at higher temperatures. This test variation is higher than the SPL differences which are typically observed for different tyre variants within a tyre development loop, see for example Figure 42a in [1]. In other words, the temperature effect is strong enough to mask the effects of noise-reducing/-increasing technological tyre modifications. This problem also exists for constant speed pass-by measurements, albeit to a much lower extend. Accordingly, for CRS pass-by measurements a temperature correction has been defined for tests which are done in agreement with UNECE R117 [3]. For accelerated pass-by measurements no such correction factor exists.

Compared to CRS measurements another problem related to the temperature influence arises from the presented data: both within UNECE R117 [3] and UNECE R51.03 [4] the allowed range of air temperatures for pass-by noise testing is defined as 5 °C to 40 °C. Compared to the observed torque effect difference of more than 1.0 dB(A) for a 19 °C temperature difference this range seems excessive, especially without temperature correction. However, limiting the allowed temperature range for accelerated pass-by noise measurements to a smaller range than 5 °C to 40 °C reduces the number of tests which can be performed within a given time period.

An additional item which affects testing operations needs to be considered as well. Pass-by measurements are usually conducted as follows: each test session contains several sets of tyres which are to be compared, e.g. the reference tyre and development variants. The test vehicle is equipped with the first set of tyres which are to be tested. The tyres are warmed up, and then the necessary number of measurement runs is performed. The vehicle returns to the garage where the next set of tyres is mounted and the process repeats. Without temperature correction, for accelerated pass-by noise measurements the temperature increase between the first set of tested tyres and the last set should be as small as possible. Especially in early and late summer, minimising this intra-test-session temperature difference can be quite challenging. As a short-term mitigation measure testing operations can be organized in such a way that unnecessary time delays during accelerated pass-by noise testing are minimised. As a long-term measure, investigations regarding a temperature correction for these measurements potentially need to be started.

In addition to the challenges related to maintaining a sensible temperature range for all tyre sets within one test session, there is the second problem that for a CRS pass-by test around eight to ten measurement runs per tyre are needed. Due to the number of target accelerations which need to be tested in an accelerated pass-by measurement the required measurement runs per tyre can double. This increases the needed testing resources and further complicates maintaining reasonable temperature differences between tyres.

3.2.3 Reducing the risk of failed target approvals due to test variation

A significant business risk is associated with the test variation which is observed for any type of tyre performance testing, including (accelerated) pass-by noise testing. Especially for outdoor testing, not all sources of test variation can be fully controlled at all times. In nearly all scenarios the test result is a stochastic quantity which follows a normal distribution. This has some consequences for the reliability of test results from a business point of view. An example: suppose that a tyre has to fulfil a pass-by noise level of 64 dB(A) according to the RFQ.

During development, this tyre is tested for pass-by noise with a resulting sound pressure level of 63.4 dB(A). The test variation, i.e. the standard deviation σ, might be 0.4 dB(A). Apparently, this seems to be a good result. However, since the test data is stochastically distributed, there is an only a 93.3 % chance that a repeated test, for example the actual target approval by the OEM, will be equal to or below the required 64 dB(A). In other words, there is still a 6.7 % chance that the tyre will not be approved by the customer even though it was tested 0.6 dB(A) below the request SPL during development. This risk can never be fully mitigated; however, it can be significantly reduced by reducing the standard deviation of the test, i.e. by improving the precision of the test. If, in the same scenario as above, σ is reduced to 0.3 dB(A), or even 0.2 dB(A), the risk for failure in a second test reduces to less than 2.5 % or 0.1 %, respectively. In a best-case scenario failing a TA necessitates further development activities with the corresponding costs. In a worst-case scenario a failed TA means that the business with the customer is lost and there is no return of investment on the development costs.

The risk of failing a TA because of the test variation is not a new problem. However, in the past TA pass-by noise testing was usually done at constant speed, see Section 2. These conditions are very well understood and additionally show a lower influence of operating conditions on the test results than accelerated pass-by testing [1]. With OE customers increasingly demanding accelerated pass-by noise testing in their TAs, the higher test variation of accelerated pass-by noise testing poses an economic risk which needs to be minimised.

According to the findings of action B7, the most critical points for the test variation of accelerated pass-by noise measurements are the test vehicle and the environmental conditions. How the influence of these conditions on test results can be minimised has been described in Sections 3.2.1 and 3.2.2. In the example in Figure 18b in the action B7 report [1] the σ_{veh} for the measurements with the two test vehicles is 0.7 dB(A). By implementing the measures discussed in Section 3.2.1 it is expected that a σ_{veh} of roughly 0.1 dB(A) to 0.2 dB(A) is achievable.

From the air temperature investigation in Section 3.2.3.1 in [1] a σ_{temp} of 0.6 dB(A) can be derived if the admissible temperature range of 5 °C to 40 °C from UNECE R117 [3] and R51.03 [4] is used. If the temperature range for the testing is limited to a temperature variation of maximum 15 °C, σ_{temp} reduces to 0.3 dB(A), and to 0.2 dB(A) if the variation is equal to or less than 10 °C. Compared to what was discussed for general tyre development purposes in Section 3.2.2, there is one advantage which makes accounting for the air temperature during accelerated pass-by noise testing easier for TA purposes: the testing is focussed on the performance of a single set of tyres. This means that temperature variations during testing are of lesser importance than during testing for development purposes where several sets of tyres need to be compared.

3.2.4 Test implementation

The content of Sections 3.2.1 to 3.2.3 indicates that testing capacities might need to be extended for accelerated outdoor noise measurements. Independent of this topic – which needs to be part of long-term global testing strategy – existing best practices and procedures for the measurement of noise under acceleration need to be checked for a potential need of adjustment or revision based on the findings of Section 3 in [1]. Testing personnel must be trained accordingly, too. It needs to be assured that test engineers and technicians understand the influence of test vehicle or air temperature on the measured accelerated pass-by SPL. In case of multi-location and/or multi-shift operations, it must be assured that all staff involved in tyre testing and tyre development follow the same procedures for test planning, setup and execution, and data processing and data analysis.

3.3 Development processes

Besides the knowledge which was gained about the importance of accelerated pass-by noise has for the tyre/road noise which is created by EVs in urban environments, and how accelerated pass-by noise testing is affected by test conditions, the other major outcome of action B7 is how the tyre development process can be optimised towards solving the exterior noise challenge in a more efficient and more target-oriented way. Such an outcome is more valuable than any individual technical solution as changed processes can easily be adopted to many different tyre development activities, whereas individual techniques might only be applicable to specific types of tyres, e.g. only to summer tyres but not to winter or all-season tyres.

The changes which resulted in the optimised tyre development processes which were used in action B7 can be separated into two different categories. The first is related to the overall topic of accelerated pass-by noise. It concerns how this relatively new metric is properly considered during the development process, the proper planning of accelerated pass-by noise tests to maximise the usefulness of the test outcome within the general development process, and how to properly evaluate the measurement results. The second category is virtual development: how it can be used to augment testing, and what specific virtual development measures can be used with a focus on accelerated pass-by noise. The suggested changes to the tyre development processes which are related to these two categories will be described in the next two sub-sections.

3.3.1 Adjustments for accelerated pass-by noise

In a traditional tyre development project for an ICEV dominated market, the main focus of the exterior noise optimisation has traditionally been on CRS pass-by noise at 50 km/h and 80 km/h. For EV applications accelerated pass-by noise has been considered as well, but in a less structured way as was the case in LIFE E-VIA action B7. Accordingly, some of the outcomes of action B7 should be adopted into regular tyre developments processes.

As a first item, accelerated pass-by noise needs to be considered as an additional metric to constant speed pass-by noise for applications with a focus on urban noise. This requires both additional steps in the technical design phase, and additional accelerated pass-by noise testing. This is necessary as accelerated pass-by noise cannot simply replace the constant speed pass-by noise metric for tyre and vehicle homologation reasons [3, 4], and because even under urban conditions constant speed driving is still an important part of the driving cycle.

From a planning perspective three points need to be considered when introducing accelerated pass-by noise testing as a standard into most tyre development projects. Firstly, coherent test results over the different developments loop within a tyre development need to be assured. Secondly, the robustness of the exterior noise performance needs to be guaranteed. Thirdly, the influence on development loop timing needs to be considered. These items will be covered in the following subsections.

3.3.1.1 Assuring coherent test results

Even if all accelerated pass-by noise testing quality measures as described throughout Section 3.2 are implemented, it is not possible to fully avoid measurement variations which are caused by different test locations, or major temperature variations. This means that prior to the first development phase a decision is needed which test location should be used during the complete development. Additionally, within each loop the testing at this location should be planned for roughly the same time of year to minimise the risk of huge temperature differences between the different tests.

A risk factor which can only be mitigated by alignment studies is when test vehicles are permanently replaced, or test track surfaces are repaved. Both cases can lead to (temporary) systematic shifts of the measurement results. Based on the B7 findings these alignment studies need to include accelerated pass-by noise as well.

3.3.1.2 Robustness of the exterior noise performance

The huge differences in accelerated pass-by noise levels which can be observed with varying operating and environmental conditions do not only pose a challenge for obtaining coherent test results; they also need to be considered in the noise optimisation of the tyre. In real life urban driving the tyre needs to perform regardless of variations in driving speed, acceleration, road surface, weather conditions, vehicle, etc. In this regard the noise optimised holistic LIFE E-VIA EV tyre which was developed in action B7 set a successful example of how this noise performance robustness can be achieved.

For practical reasons it is not possible to develop such a robustness purely by testing. The number of needed tests for different road surfaces, vehicles, etc. is too high, especially in view of the additionally needed time and the added costs. Within action B7 this robustness was instead assured in the design and virtual development phases of the tyre development. In the design phase additional robustness was for example achieved by accounting for the fact that on different roads different source mechanisms dominate the noise generation. In regular product development a similar adjustment to the specific roads of the market could be included. Preference should also be given to design features which improve the noise performance not only under very specific conditions but for a broad range of operating conditions.

3.3.1.3 Development loop timing

Besides the constraints on the development project timing which are needed to assure coherent accelerated pass-by noise testing, see Section 3.3.1.1, also additional small-scale intra development loop planning is needed. First of all, with accelerated testing being done in addition to CRS pass-by measurements, in total more time is needed for tyre/road noise testing. This needs to be accounted for in the development loop time planning.

From an efficiency point test planning and timing should assure that CRS and accelerated pass-by noise testing are done in conjunction with each other. This not only simplifies planning and timing, but it also assures that the same set of test tyres can be used for the two tests. Otherwise an unnecessary economic and ecologic burden is created from doubling the amount of test tyres which are needed for noise testing. Besides building and shipping costs, the negative ecological impact in terms of material and energy usage, Greenhouse gas emissions, unnecessary waste, etc. should as well be avoided as much as possible.

3.3.2 Virtual development

Even though Computer-Aided Engineering (CAE) is an integral part of Continental’s standard tyre development process, for the noise optimisation in LIFE E-VIA action B7 it was used to a larger extend and in novel ways compared to standard development projects. In particular, CAE tools were used in novel ways to account for acceleration effects in the pass-by noise prediction, the scalability of CAE solutions was used to assure noise performance robustness by considering many different operating conditions, and one development loop was a purely virtual development loop relying only on simulations and no testing. How these items can be used to advance the noise optimisation in Continental's standard tyre development projects is outlined in the following.

3.3.2.1 Novel use of CAE tools

In a similar vein to the historic focus on constant speed conditions for pass-by noise testing, see Section 3.2, also standard virtual prediction tools for exterior noise have historically neglected acceleration or torque effects. In view of this action B7 used existing virtual development tools in novel or modified ways to qualitatively assess parts of the accelerated pass-by noise performance for different tyre designs. This means that the focus of the simulations was on individual noise generation mechanisms which are known to be important under acceleration, and try to predict relative differences between tyre designs for these mechanisms.

Based on the success of this approach within action B7, it is planned that this methodology of focusing on individual mechanisms will be used for the bulk of the virtual development for exterior pass-by noise performance. Compared to full scale explicit rolling tyre finite element simulations (FEM) such an approach is faster and more cost efficient. Besides speeding up development and reducing costs, such an approach also allows for a more agile development because it is easier and less costly to create and simulate additional tyre design versions to test different approaches.

3.3.2.2 Assuring performance robustness by virtual development

Traditionally, only a few different operating conditions are considered for the exterior noise predictions in the virtual development phase of a tyre development. This can be justified by the profound experience which exists about the influence of operating conditions on CRS pass-by noise. As was seen in Section 3.2 of [1], there is much more variation in pass-by noise levels under acceleration because of exterior conditions than was the case for CRS pass-bys only. As a consequence, in action B7 noise performance predictions were carried out for a larger number of different operating conditions than is usually the case in a tyre development. The idea being that a prediction robustness would be guaranteed which helps assuring that the final tyre performs well under the multitude of different operating conditions which can be encountered in urban driving with an EV. The success of this approach was proven by the robust noise performance of the final LIFE E-VIA tyre under different operating conditions, on different roads, and with different test vehicles.

In order to achieve this robustness different sets of input data were used for the noise prediction tools which have been described in the previous section. Examples of these input data variations include speed, inflation pressure, tyre load, acceleration, indoor/outdoor test, vehicle camber, road inclination, etc. Each tyre variant was simulated under the complete set of different conditions. Based on this, strengths and weaknesses for certain conditions could be compared between the different variants.

For future tyre line developments an assessment of relevant operating conditions for the target markets can be made. All of these conditions can be included in the virtual predictions. Because of the efficiency and scalability offered by high performance computing (HPC) cloud services there is very limited impact of the number of simulations on project timing or costs.

3.3.2.3 Virtual development loops

For timing and cost reasons the second development loop in LIFE E-VIA action B7 was a completely virtual development loop in which the performance assessment of the tyre was solely based on simulation tools. While this approach worked quite well within the somewhat limited scope of target performances of action B7, this approach cannot be 100 % translated to full-scale tyre development. Even though there is clear cost advantage from virtual testing the uncertainties surrounding CAE predictions are currently still too high to justify completely replacing real world testing by virtual testing.

However, what is conceivable is the introduction of *ad hoc* intermediate virtual development loops into the regular development cycle. These could for example be used in parallel to tyre building and testing of selected, preferred development variants. The outcome from this virtual loop could then be used together with the test results from the build tyres as starting point for the next development phase.

Another scenario where in-parallel virtual development might be useful is linked to the testing. It occurs when tests results of special significance are obtained early in the test phase. A short virtual loop based on these test results could be started as a form of pre-development for the next development phase.

4 Summary

The objective this deliverable to LIFE E-VIA action E2 was to investigate the exploitation actions for the methods and processes which facilitated the development of the holistic noise optimised EV tyre for urban applications in action B7. Though this development made use of technical solutions, these were not novel but well-established and validated. The novelty in B7 was in the target-oriented integration of these technologies which was used to achieve the desired noise and target conflict performances. One enabler for this smart integration was the additional know-how which was gained during action B7 on how to incorporate accelerated pass-by noise testing into the tyre development process in the best way. The other enabler was the adaption of development processes to the special requirements of the holistic noise optimised EV tyre. In this deliverable scenarios for the exploitation of both of these two enablers for tyre development processes were presented.

For the accelerated pass-by noise testing it was concluded that a significant business risk is created from the additional measurement uncertainties which are introduced by the accelerated pass-by noise testing. It was concluded that testing conditions, especially in terms of used test vehicle and meteorological conditions, need to be tightly controlled to minimise the risk of failing target approvals due to test variations. In view of this a particular focus was laid on the measures and best-practises which are needed to minimise the impact of test variations as were observed in Section 3.2 of the B7 report [1].

With respect to adaptations of the tyre development process the first point which was investigated for the exploitation concept was how to properly account for accelerated pass-by noise during the tyre development design, simulation and test phases. It was shown that a robust and efficient noise prediction during the development process is possible by simple adaptations to existing prediction tools. It was also investigated what would be needed to assure coherent test results throughout tyre development project.

One of the development loops in action B7 was a virtual loop relying purely on numerical simulations and virtual prediction tools. It was investigated how such virtual loops could be used as an enhancement to a regular tyre development process.

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