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Traditional Product Development Process Versus Design Thinking and a Case Study of a Drum Test Rig with Adjustable Impact Bars

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There are currently two development strategies in the product development process. In the traditional process, concepts emerge from combining alternatives across various parameters. The Design Thinking method, on the other hand, focuses on customer needs and the development team. Both approaches are briefly explained below.

Traditional product development

The traditional product development process starts with a systematic analyze of a problem, to find all possible solutions. In the table called morphological box, Table 1, the problem is broken down into its essential parameter or features. Brainstorming is required to find as many alternatives as possible for each feature. The results are collected in the morphological box. This provides a systematic overview of all possible variants and combinations that could lead to a solution.

Feature	***Alternative***		
Material	Plastic	Metal	Carbon-fiber-reinforced plastic
Drive	Electric	Hydraulic	Pneumatic
Motion	Translation	Rotation	Translation & Rotation
Switch	Touch	Toggle-switch	Rotary-switch

Table 1: Morphological box.

This approach is analytical and structured. It involves systematizing and combining possible solutions without immediately working with customers or developing rapid prototypes. It focuses on technical or functional feasibility. The process in the morphological box is usually not iterative, but a one-time analysis. The model itself is less flexible and is often used to gain a clear overview of the possible technical variants.

Typical application of the morphological box
Solving technical problems

When developing new technologies or products, where many different technical parameters play a role.

Innovation processes

When it is a matter of exploring all conceivable variants and solutions before making a final decision.

Complex design problems

When several factors such as material, costs, functions and design have to be taken into account.

Advantages of the morphological box

Systematic approach: It helps to consider all relevant solutions and not to overlook any important options.

Promotes creativity: By combining different alternatives, unexplored solutions are often found.

Transparency: All solutions and their possible combinations are clearly visualized and can be easily analyzed.

Product development with design thinking

Design thinking method is strongly focused on the needs and desires of users or customers. It is about developing empathy with users and finding innovative solutions that address these needs. Design thinking often follows a clearly structured process, consisting of the phases: *understanding, defining* (clearly outlining the problem), *ideation, prototyping* and *testing*. The development team typically consists of people with different expertise, which leads to more creative and different solution strategies. There is an emphasis on teamwork and brainstorming. Another central aspect of design thinking is the iterative process. After each phase, a prototype is built, tested and then adjusted, based on the experiences. There is no fixed order of phases – they can be repeated or adapted based on feedback and insights.

Advantages of the design thinking methode:

- The needs and desires of end users are at the focus of solution strategy.
- It promotes creativity and innovation
- Teamwork and interdisciplinary collaboration lead to new perspectives and diverse solution approaches.
- The method is adaptable to deal with change.
- Quick testing of ideas through prototyping and testing is possible. This minimizes the risk of failure.
- Focusing on empathy helps to develop a deep understanding of user challenges and ensure, that solutions meet their needs.
- The results have high practical benefit.

Overall, design thinking leads to innovative, well-thought-out solutions that benefit both users and the teams involved and often lead to positive changes in processes and products.

Main differences between design thinking and Traditional approach

User orientation: Design thinking is strongly user-centered, morphological box focuses more on functional and technical dimensions.

Process: Design thinking is iterative, morphological box is more of a one-time analysis process.

Interdisciplinary versus structure: Design thinking promotes creativity and interdisciplinary collaboration, morphological box is a structured, analytical approach.

Prototyping: Design thinking relies on quick prototypes; morphological box usually does not require immediate prototypes.

Similarities

Both methods aim for innovative solutions. Both can help identify and develop product solutions by approaching the problem in a structured way. Both methods can be supported by artificial intelligence (AI).

Product development and AI

The strength of AI lies in the quick analysis of large amounts of data and the ability to recognize patterns that are relevant to the design process. In the product development, this leads to a faster process and the efficiency increases. The development team gets deeper insights and is able to focus on creative processes. The outcome of an AI supported development process could be a more precise and more data-driven result.

In the Traditional product development process, AI can automatically check all possible combinations and prioritize the solutions with the highest chance of success or the best results based on historical data. With its property to recognize patterns and relationships, AI can help to discover unrecognized interdependencies between different features and show which combinations best fits the desired requirements that were not previously obvious. Simulating scenarios or prototypes saves time and resources. So iterative improvements based on feedback become possible and the Traditional product development process can be continuously adapted to new requirements.

For the design thinking method, AI can automatically extract important insights from interviews, surveys and behavioral analysis and help the design team to understand the customer desire better and to prioritize user needs. AI can support ideation and creativity by providing inspiration and highlighting unused solution approaches. AI could recognize design patterns or successful solutions from other areas or make suggestions that the team can use in the ideation phase. Simulating scenarios or prototypes also saves time and money and the solutions can be tailored more to the individual needs of users. Or answers the question, which design ideas have the greatest potential.

To summarize both methods, the morphological box might be more useful when a product is to be developed using a technical or functional approach based on the study of all possible variants. Design thinking is probably the better choice when a product is to be developed that focuses on the needs of the users, because it works iteratively and includes direct feedback.

Not every product is designed for an end customer, and not every development department can afford an interdisciplinary development team. The functionality of a technical product is usually the primary focus. An example from a development process in the bicycle industry illustrates the traditional product development process for a drum test rig.

Testing Background

Durability tests for EPAC (**e**lectrically **p**ower **a**ssisted **c**ycles) are carried out according to DIN EN 79010 and DIN EN 15194. If the tests are carried out on drum test rigs, both standards require a specification for the drum diameter. In DIN EN 79010 it is at least 400 mm. In DIN EN 15194 the drum diameter must be between 500 mm and 1000 mm. For reasons of space, the smallest specification that meets both standards are often used as a guide.

DIN EN 79010 requires a test in three stages. The first stage requires 250,000 impacts at an impact bar height of 15 mm ± 1mm and a peripheral speed of 15 km/h ± 1.5 km/h. The second stage also requires 250,000 impacts and a peripheral speed of 15 km/h ± 1.5 km/h. However, the impact bar height is now 30 mm ± 1mm. These two tests are intended to depict driving on rough roads. The third stage simulates driving down a curb. Therefore, the impact bar height is 70 mm ± 1mm and the peripheral speed is only 3 km/h ± 0.3 km/h. The number of impacts in this stage comprises 25,000 repeats.

The dynamic test according to DIN EN 15194 is only an one-stage test, but it requires 750,000 bar impacts at a peripheral speed of 25 km/h ± 10%, an impact bar height of 10 mm ± 1 mm and a radial force of 640 N per wheel. Table 2 and 2 summaries test condition of DIN EN 79010, [1] and DIN EN 15194, [2].

	Impact bar height [mm]	***Rim speed [km/h]***	***No. of impacts***
stage 1	15 ± 1	15 ± 1.5	250.000
stage 2	30 ± 1	15 ± 1.5	250.000
stage 3	70 ± 1	3 ± 0.3	25.000

Table 2: Test stages according DIN EN 79010.

Impact bar height [mm]	***Rim speed [km/h]***	***No. of impacts***	***Radial force per wheel [N]***
10 ± 0.25	25 ± 10%	750.000	640

Table 3: Test steps according DIN EN 15194 and DIN EN ISO 4210-7.

The trend at EPAC is towards larger and heavier vehicles with multi-tracks. Current EPACs have a permissible total weight of up to 750 kg [3], a length of up to 3400 mm and a track width of up to 1160 mm [4]. With these parameters, the vehicles belong to the EU type classes L1e-A to L1e-B (Fig. 1). It is therefore not easy to move them on the test bench and convert the impact bar height while they are on the test rig.

Elektrofahrrad-Typ	EU-Typ-genehmigung	Fahrzeugart	Höchstge-schwindigkeit [km/h]	max. Leistung [W]	Versicherungs-kennzeichen	Helmpflicht	Betriebs-erlaubnis	Alters-beschränkung	Promille-Grenze	benötigte Führerschein-klasse	Radweg-benutzung	Personen-transport im Anhänger
Pedelec	-	Fahrrad	25 mit Treten 6 ohne Treten	250	nein	nein	nein	-	1,6 ‰	-	ja	ja
	L1e-A	Fahrrad	25 mit Treten	1000	nein*	nein*	nein*	-*	1,6 ‰*	-*	ja*	ja*
S-Pedelec	L1e-B	Kleinkraftrad	45 mit Treten	1000	ja	ja	ja	16	0,5 ‰	AM	nein	nein
E-Bike	L1e-B	Leichtmofa	20 ohne Treten	4000	ja	nein	ja	15	0,5 ‰	allgemeine Fahrerlaubnis oder Mofa-Führerschein	nur bei Freigabe Mofa/E-Bike	nein
	L1e-B	Mofa	25 ohne Treten	4000	ja	ja	ja	15	0,5 ‰	allgemeine Fahrerlaubnis oder Mofa-Führerschein	nur bei Freigabe Mofa/E-Bike	nein
	L1e-B	Kleinkraftrad	45 ohne Treten	4000	ja	ja	ja	16	0,5 ‰	AM	nein	nein

* Da der Redaktion keine Regelungen in deutschen Gesetzen zu Pedelecs zwischen 250 und 1000 W bekannt sind, wurden die rechtlichen Bestimmungen von Pedelecs mit maximal 250 W übernommen. Die Verordnung (EU) Nr. 168/2013 vom 15. Januar 2013 klassifiziert Pedelecs zwischen 250 und 1000 W als Fahrräder.

Figure 1: Legal regulations for electrical bikes in Germany, Source: Forschungs informations system [5].

Requirements Specification for a test rig

Given the varying dimensions and weights of EPACs—which may feature three, four, or—with a trailer—even six wheels—it makes sense to develop a test rig capable of performing most of the tests required by current standards (DIN EN 79010 and DIN EN 15194) on multi-track and heavy EPACs without needing to transfer the vehicle to a different rig. Another requirement reflecting real-world conditions is that the rig must support a load of 200 kg per wheel. Such loads necessitate wide tires; therefore, the rig must accommodate tires up to 250 mm in width. Both DIN standards mandate tests using drums, requiring a minimum drum diameter of 500 mm. The height of the impact bars varies; they must be capable of extending from 0 mm to 70 mm. S-Pedelecs can reach speeds of up to 45 km/h (see Fig. 2), so the rig must support testing at this speed. The parameters, such as the impact bar height $\mathbf{h}$ and the drum speed $\mathbf{v}_{si}$, must be varied during the test during the drums are rotating. Parameters such as the EPAC speed, the motor power or the braking forces must recordable. The maximum speed of the EPAC should be 45 km/h. At maximum speed all the bars are retracted. The maximum speed with impact bars should be 40 km/h. Preliminary work can be found in [7-9].

These are all technical specifications required by the legislature or the market. Demands that provide clear direction for creativity during the product development process.

The Test rig

Due to their size and weight, it is difficult to place these vehicles on a test rig or to move them from one test rig to another. Consequently, there is a desire to develop a test rig capable of performing most of the tests required by applicable standards (DIN EN 79010 and DIN EN 15194) on large and heavy EPACs without the vehicle having to be moved to a different rig.

A suitable approach is a test rig with four or six independent roller drums. Each drum can be loaded with a weight of up to 200 kg. Each drum should be equipped with adjustable impact bars that can be extended during operation in order to meet the required test levels of the standards and to be able to travel a specified route profile without stopping. The road profile can contain plane roads, bad roads, inclines or curbs. All impact bars are wide enough to be able to place EPAC with tire widths of up to 250 mm on the drums [6]. The test programs from the regulations according to DIN EN 79010 and DIN EN 15 194 are possible to check.

Since the drum modules are not mechanically coupled, there are high demands on the control unit of the interconnected drum modules in order to ensure the synchronism of the impacts, as in the field. If a vehicle hits a pothole on the road, the distance between the impacts on the front and rear wheels is just the wheelbase. The drums for the front axle and the drums for the rear axle therefore have to be adjusted by a fixed angle difference, which corresponds to the wheelbase in the beginning of the test. In order for this to happen exactly on the test bench, the drums must rotate angularly synchronously. However, when driving over the impact bar, the drive torque and the rotation speed of the drums change. In order to maintain the angular synchronism of the impact bars with each other, the accelerations of the drums must be varied with each impact [10].

In particular, multi-track EPACs should be tested. In order to cope with the dimensions of these type classes and be prepared for the future, a modular test bench has been built. Both single-track and multi-track EPAC can be put to the test rig. The wheelbase and track width is flexibly adjustable thanks to the modular design with e.g. four individual drums and the arrangement on a grooved plate. With the help of springs and tension straps on the cage, the EPAC is flexibly fixed to the drum units (s. fig.:3).

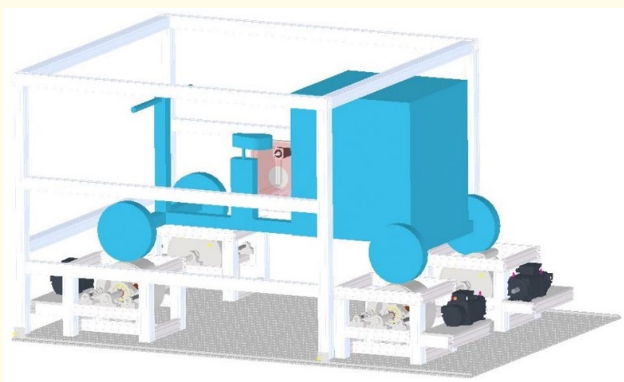

Figure 2: Design of the test bench [9].

One open issue for which there are no specifications is the extension and retraction of the impact bars. This problem is addressed below. Extending and retracting the impact bars is a technical challenge where the morphological box can provide further assistance. This tool clarifies the problem and its individual characteristics, enabling a structured approach to the task. The morphological box for moving the impact bars is shown in Table 4. The possible parameters are shown in the left column, and the possible alternatives in the adjacent columns.

Feature	***Alternative***			
Type of motion	axial to the drum	radial to the drum	rotating	
drive	mechanical/electrical	pneumatic	hydraulic	
Motion-executing component	cylinder	gear wheel	threaded spindle	Linear actuator
relative motion with respect to the rotating drum	co-rotating	non-rotating		
Energy supply to the rotating drum (electricity, air pressure, fluid)	available	not available		

Table 4: Morphological box for the impact bars.

The concepts resulting from this morphological box are described on the following pages.

Gear wheel concept

The first concept to be presented is the gear wheel concept. It works similarly to a manual car window winder [8]. F.3

The motion executing component is the gear that gives the system its name. The relative rotation of the gear with respect to the drum causes the impact bars to extend or retract (s. Fig 3a and Fig. 3b). This adjustment is performed mechanically. For the concept to function, the gear must rotate along with the rotating drum. Consequently, the gear's drive mechanism must also rotate, necessitating a power supply within the rotating drum. The entire gear is mounted on the splined shaft via a rolling-element bearing, allowing it to rotate. It is connected to a torque motor that is mounted on a splined shaft and rotates with the drum; the torque motor thus drives the gear as well.

To implement the concept, it must first be verified whether the torque motor's performance meets the requirements. The object under test is to exert a load of no more than 200 kg per drum. The maximum load placed on the motor by the gravitational force is, when the EPAC wheel acts on the tip of the impact bar. Expecting a lever of 100 mm the gravitational force generates a torque 200 Nm about the axis of rotation. The impact force at 15 km is even greater, (s. Table 5). The most powerful torque motor that can still be accommodated within the drum has a maximum holding torque of 98 Nm. Even when estimating the torque required solely for the holding function, it becomes clear that this concept is unsuitable.

A similar problem arises with the linear actuator concept. The actuators that can be installed in the narrow drum are not powerful enough to keep the impact bars extended under load.

Umbrella concept

The next concept to be presented is called the umbrella concept [8]. The lifting mechanism is designed in such a way that the impact bars extend and retract like opening and closing an umbrella. (see fig 4 , 5, 6 and [11]). A carriage is shifted axially along a shaft and pushes the impact bars outwards—or pulls them inwards—via struts. Estimating the forces acting under the specified loads and geometry appears promising, so this concept is being investigated in greater detail.

Design of the components

It quickly becomes clear that the simulation of bad roads conditions requires a different impact bar geometry, such as driving over a curb. For this reason, the drum has two types of bars. Small impact bars that can be extend from zero to 30 mm, are developed for the rough road sections. These can be used, for example, to simulate roots and small potholes. For curb crossing the impact bars must be larger. These big impact bars extend up to 70 mm. In the retracted position, its shape must conform to that of the drum shell to enable smooth rolling at high speeds. In order to keep the test times as short as possible, four small and two big impact bars were distributed around the drum circumference. A symmetrical arrangement of the bars makes sense to compensate the imbalances (see fig.7).

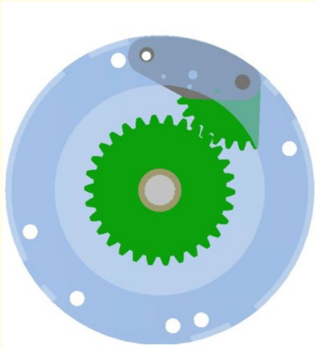
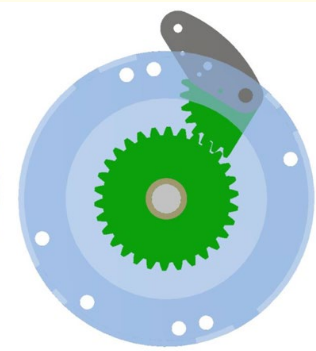

Figure 3a: Retracted impact bar. ***Figure 3b:*** Extended impact bar.

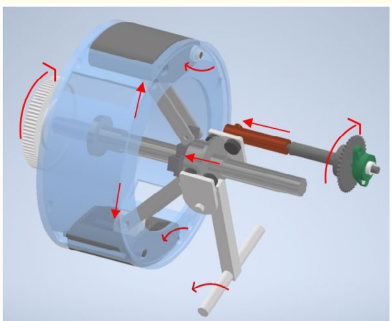
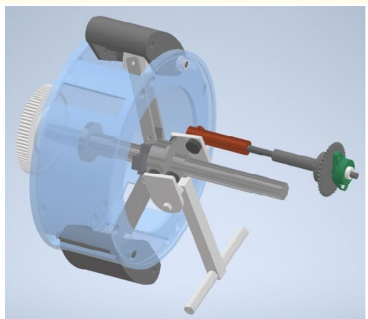

Figure 4a: Retracted impact bar. ***Figure 4b:*** Extended impact bar.

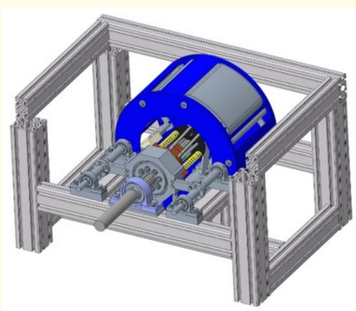
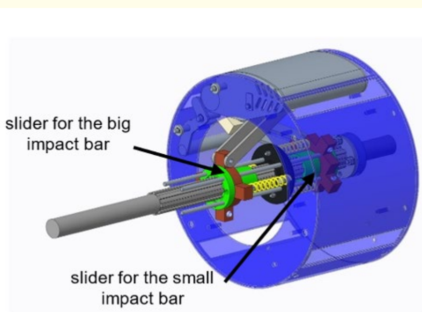

Figure 5: Drum module with housing. ***Figure 6:*** Drum with impact bars.

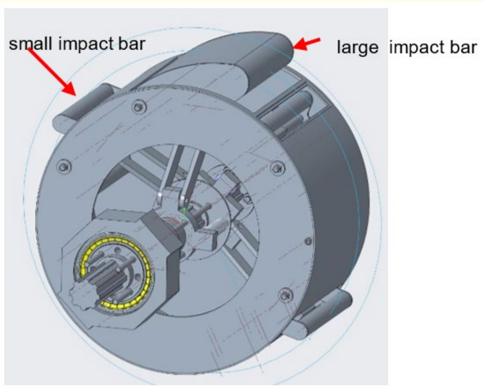

Figure 7: Arrangement of the small and large impact bars.

It does not seem to make sense to drive over curbs and on rough roads at the same time. The adjustment mechanism for the bars was therefore developed in such a way that either no impact bar is extended, only the small impact bars are extended between zero and 30 mm or the two big impact bars are extended up to 70 mm.

Finite Element Analysis for the components

It is notable that the acting force increases as wheel diameters decrease [7]. This is an important point, as small wheels are typically fitted to the cargo platforms of electric cargo bikes to keep the center of gravity and the loading edge low. The trend for the horizontal force is similar, albeit with lower values. To determine the maximum force, Table 5 lists the horizontal (FH) and vertical (FV) load acting on a 10-inch wheel, with respect to the height (h) of the impact bar and velocity (v) based on the test levels specified in the DIN standards.

Maximum force [N]	***h =15 mm; v =15 km/h***	***h =30 mm; v =15 km/h***	***h =10 mm; v =25 km/h***	***h =30 mm; v =40 km/h***
F_H small bar [N]	1769	3049	1053	6668
F_v small bar [N]	4552	5137	5752	11233
F_H big bar [N]	1146	2484	1561	5812
F_v big bar [N]	4404	5026	5500	10817

Table 5: Forces at the impact bars.

If the drum modules are set up in that way, that the adjustment unit for lifting the impact bars is on the outside, the rotation direction of the drums on the left and right side is reversed. The geometry of the large impact bar is symmetric. The lifter is in the middle of the impact bar. So, for the big impact bars only the bearing shaft has to be moved from left to right, if the rotation is clockwise or counter clockwise. In the FEA- simulation for the drum with the large impact bar extended to h =70 mm and a velocity of 3 km/h, three load cases are considered: curb ascent, curb descent and largest lever at curb descent. Figures 8a, 8b and 8c illustrate this. The acting force on the impact bar when driving up the curb is 1500 N. The load in the two other load case results from the required weight force of 2000 N per wheel.

The greatest stresses and deformations occur in load case 1 (curb ascent). The simulation of driving up the curb. The whole drum is deformed. The greatest displacement occurs at the tip of the impact bar. It is 0.8 mm, see figure 9. The highest stress in this load case occurs at the weld seam of the clamping point of the bearing shaft, see figure 10.

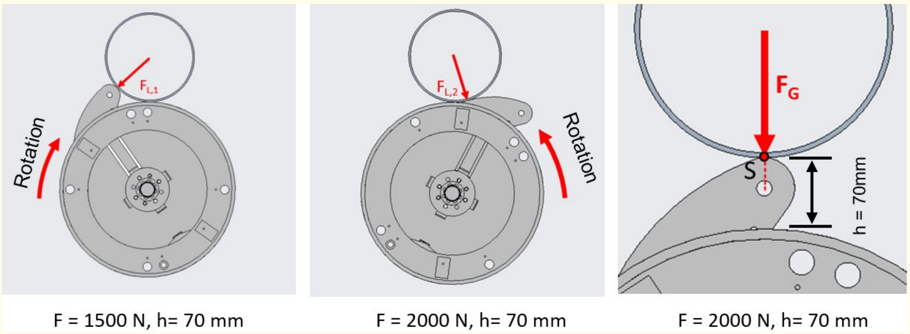

Figure 8a: Load case 1, curb ascent. ***Figure 8b:*** Load case 2, curb descent. ***Figure 8c:*** Load case 3 largest lever.

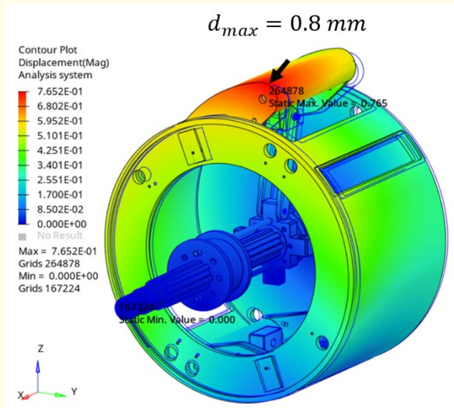

Figure 9: Deformation during curb ascent.

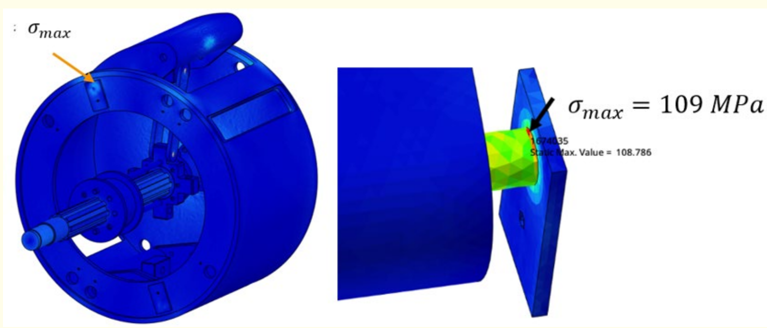

Figure 10a: Deformation during curb ascent. ***Figure 10b:*** σ_{max} during curb ascent.

All stresses shown are von Mises equivalent stresses. The stresses in the second load case (curb decent) are lower than in the other two load cases with 0.5 mm displacement and σ_{max} =29 MPa They are not shown. In load case 3, the largest lever, the deformations are limited locally to the impact bar. At 0.7 mm, they are smaller than in the curb drive. The situation is different with the stresses. Here, too, the greatest stress occurs in the weld seam of the bearing shaft. But with σ_{max}= 221 MPA they are twice as much, then in load case 1 the curb ascent, see Figure 11.

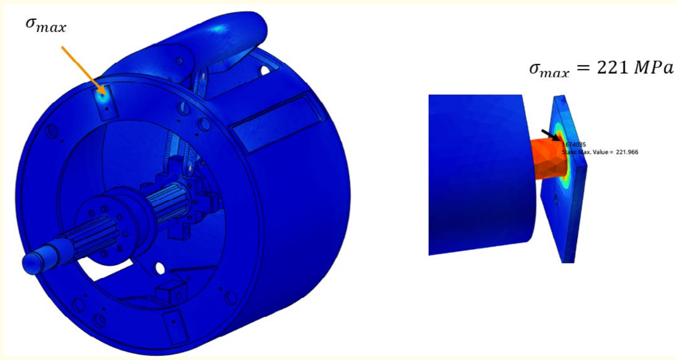

Figure 11a: Deformation during curb descent. ***Figure 11b:*** σ_{max} during curb descent.

At the end of the investigation on the large impact bars, the effects of driving onto the curb at 12 km/h is simulated. The result is, the displacements are doubled compared to the ascent with 3 km/h and the highest stress is now with 238 MPa comparable to that in the load case of the largest lever.

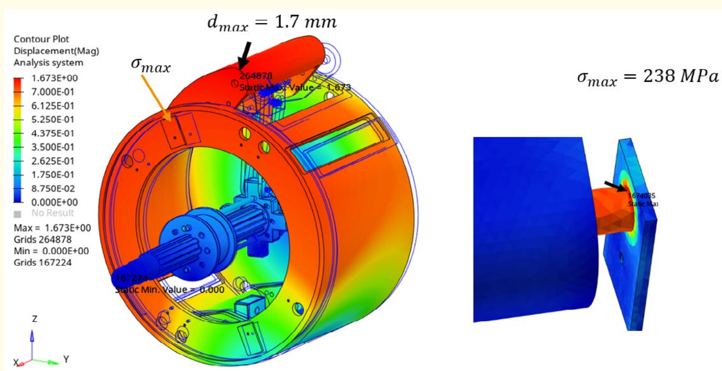

Figure 12a: Deformation during curb ascent with 12 km/h. ***Figure 12b:*** σ_{max} for curb descent with 12 km/h.

Since the test bench shows no damage to the large impact bars, the simulation is terminated.

The situation is different for the small impact bars. In the side view, the small impact bar has an L-shape. Here, the connection between the lifter shaft and the L-shaped side part tears in the corner of the L. In figure 13 the arrangement of the four small impact bars is shown. Figure 14 shows the damage between the lift shaft and the side part in the corner of the L.

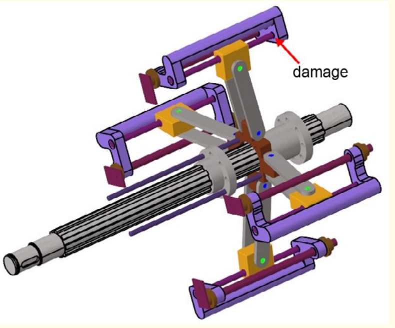

Figure 13: Arrangement of the small impact bars.

Figure 14: Damaged small impact bars at L-shaped side part.

Depending on the rotation direction, clockwise or counter clockwise, the L-shape is bended close or open. Due to that, two load cases are considered. One for the bend close of the L-shape and one for bend open the L-shape. Figures 15a and 15b illustrate the two situations.

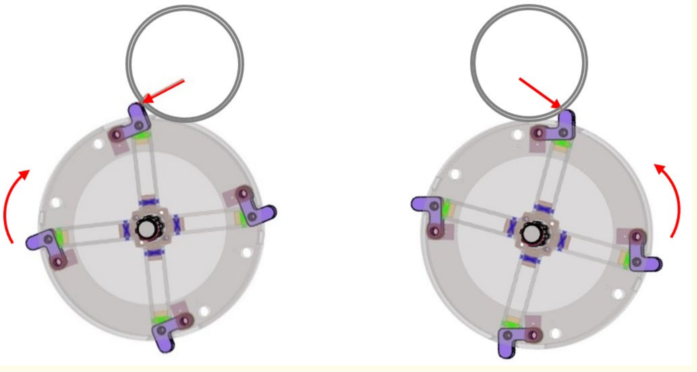

Figure 15a: Geometry and forces for the small impact bar. Load case 1, L-shape bend close.

Figure 15b: Geometry and forces for the small impact bar. Load case 2, L-shape bend open.

In load case 1, where the drum rotates clockwise, the impact goes in the direction of the bearing. In load case 2, the impact goes away from the bearing. In both cases the bar is pressed onto the lifting mechanism.

Based on Table 5, a load of 13,000 N is chosen for both cases. To simulate that the EPAC is not positioned exactly in the middle of the drum, the acting force was also shifted to the right and left on the impact bar. The drum and the splined shaft show the greatest stress where the force application point has the largest lever arm. In the figures 16 and 17 this simulation result are shown. The values in the two load cases bend up and bend close the L-shape are similar. The displacements and stresses are slightly higher, when the drum rotates clockwise (bend close). Clockwise, the largest displacement is just under 4.5 mm, counter-clockwise 4.6 mm. The stresses behave analogously. Clockwise, the maximum stress is σ_{max}= 700 MPa, counter-clockwise it is σ_{max}= 708 MPa. In both cases, the point is in the tooth base of the splined shaft, close to the point where the drum is attached to the splined shaft and results from the ideal rigid bearing of the shaft with rigid body elements. No damage occurs at this point on the test bench, so this point is ignored.

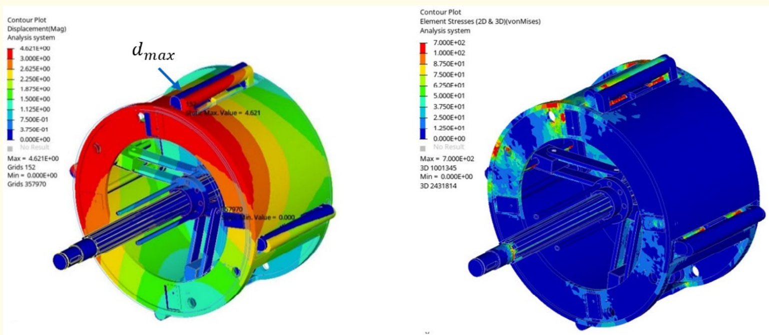

Figure 16a: Displacements load case 1, bend close. ***Figure 16b:*** Stresses load case 1 bend close.

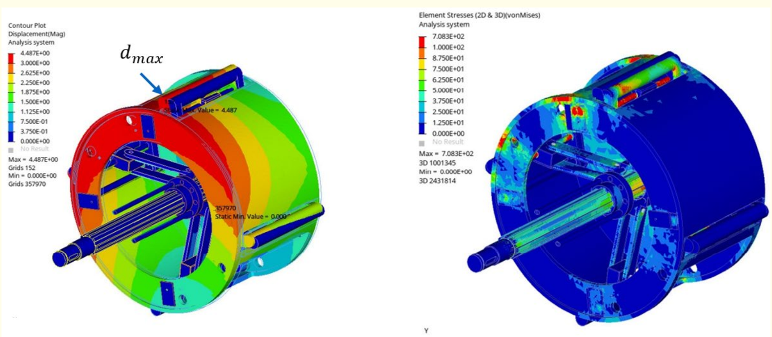

Figure 17a: Displacements load case 2 bend open. ***Figure 17b:*** Stresses load case 2 bend open.

If we look at the point where the small impact bar fails, we see a stress concentration in the FEA model, see figure 18 and 19. But the greatest stresses occur on the impact bar when the force application point is closest to the drum bearing. For load case 1 (bend close) the stress analysis shows σ_{max}= 497 MPa. In load case 2 (bend open) the stress maximum is σm_{ax}= 446 MPa. This means that when the L-shape is bended up, the maximum stress is 10% lower than when the L-shape is bended close. The stress level in both cases is high. But the difference of 10 % is enormous, because in fatigue analysis, the rule of thumb says, that a 10% reduction in stress means a doubling of the endurance. From this, we can conclude that the small impact bars are most likely to fail when the L-shape is bended close.

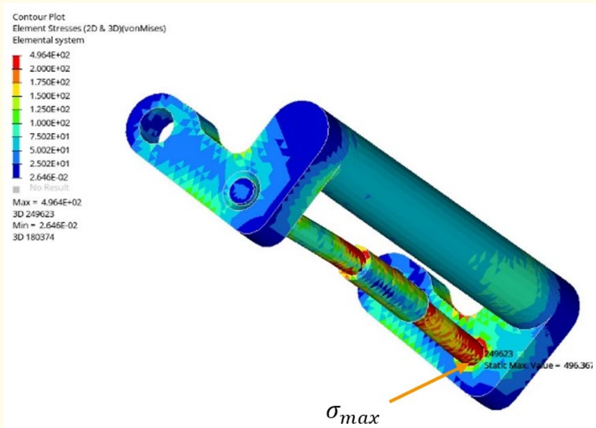

Figure 18: σ_{max}=497 MPa , small impact bar load case 1, bend close.

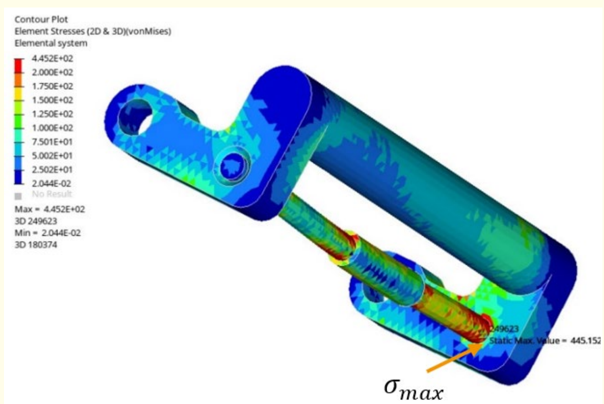

Figure 19: σ_{max}=446 MPa , small impact bar load case 2, bend open.

The following changes (fig. 20) were made to reduce stress levels [12]. The thickness of the L-shaped side panels was increased from 10 mm to 20 mm, and the bearing points were bored out and fitted with nylon bushings. This softer mounting allows the energy from impacts to be converted into elastic deformation work and dissipated.

Consequently, the stress shifts to the inner side of the side panels. The peak stress drops from 497 MPa to 317 MPa. Although this value remains high—well above the fatigue limit—such extreme impact loading (involving a 200 kg load per wheel and 30 mm high impact bars at 40 km/h) will not occur during every test s. table 5. These measures significantly extend the service life of the small impact bars.

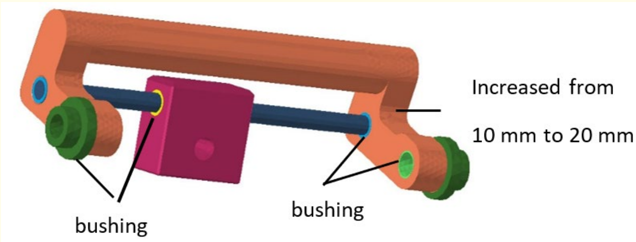

Figure 20: Changes to reduce the stress level.

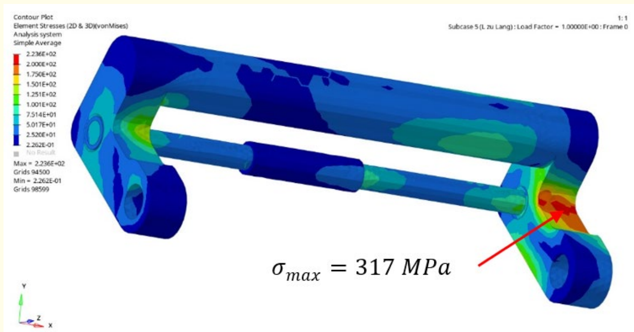

Figure 21: Reduced stress level, small impact bar loadcase 1, bend close.

Conclusion

Not every product is intended for end customers, and not every development team can afford the luxury of an interdisciplinary team. This is why development based on traditional methods remains valid. The approach is illustrated using a test rig for the bicycle industry. Multi-track cargo bikes are so large and heavy that it is not easy to move them on the test bench and convert the impact bar height while they are on the test rig. Drums with extendable impact bars have the benefit, that the bars can be lifted and retracted while driving. In order to be able to test a road profile with driving on flat roads, bad roads and driving on curbs, two types of impact bars are useful. Large impact bars for curb crossing and small impact bars for rough road conditions. The four smaller impact bars can be lifted up to 30 mm. The two larger impact bars extend up to 70 mm. Loading the large bars under conditions as specified in DIN EN 79010, they fulfil their task. However, it is noticeable that the small impact bars are exposed to greater load and fail when operating the test bench and in the calculation. The damage could be reproduced in the FEA model. In addition, the simulation shows that the direction of rotation has a significant influence on the endurance of the test rig. Whether the drum rotates clockwise or counterclockwise, there are two load cases. Clockwise the L-shaped impact bar is bended close; counterclockwise the bar is bended up. The displacements in both load cases are comparable. But the stress level in the load case, the L-shaped impact bar is bended close is higher than in the case, where the drum rotates counterclockwise.

References

1. DIN 79010:2020-02. Cycles – Transport and cargo bicycles – Requirements and test methods for single-track and multi-track bicycles, Annex D: Testing of vehicles on a test rig. Berlin: Beuth Verlag GmbH (2020).
2. DIN EN 15194:2018-11. Cycles – Electrically power assisted cycles – EPAC, Annex H: Wheel/tyre assembly – Dynamic test (EN

15194:2017 (D)). Berlin: Beuth Verlag GmbH (2018).
3. VOWAG Cargo Bikes. VOWAG GmbH (2021).
4. Ono Onomotion GmbH (2021).
5. Research Information System. Legal classification of electric bicycles (2021).
6. A.N.T. Cargo. A.N.T. GmbH (2021).
7. Nauerz A. “Development of a modular drum test rig with adjustable impact bars”. Research report, Mannheim University of Applied Sciences (2020).
8. Matveev V. “Development of a roller test rig with adjustable impact bars”. Bachelor’s thesis, Würzburg-Schweinfurt University of Applied Sciences (2020).
9. Durmus A. “Development of a test rig for multi-track EPACs”. Bachelor’s thesis, Würzburg-Schweinfurt University of Applied Sciences (2020).
10. Can M. “Drum test rig drive systems and power measurement for EPACs”. Bachelor’s thesis, Würzburg-Schweinfurt University of Applied Sciences (2021).
11. Nauerz A. “Test rigs for multi-track cargo bikes”. Proceedings of the 8th International Conference on Intelligent Technologies, Jakarta (2023).
12. Schwegler N. “Finite element analysis of a drum test rig with extendable impact bars for simulating curb impacts and rough road sections”. Master’s thesis, Mannheim University of Applied Sciences (2025).