Design of Sliding Frame System for Two-Wheeled Vehicle

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Abstract

The article deals with the initial design of a system for changing the adhesive force of two-wheeled vehicles. The system is designed for light off-road motorcycle KTM 250 SX-F. The purpose of the system is to allow the adhesive force transmitted between the motorcycle wheels and the road to be changed. The system allows the motorcycle rider to move the motorcycle at the stability limit at 'safe' speed. Both from the forward and especially the transverse direction. It also prevents damage to the rider's health and motorcycle if the limit value is exceeded. The system is designed as two hydraulically operated frames, one for the front and the other for the rear motorcycle wheel. The change in adhesive force is controlled by reducing the radial response transmitted by the motorcycle wheels. Depending on the desired situation, it is possible to simulate a reduction in adhesion by any value independently for the front or rear wheels or together for both wheels. A pair of drop frames comes into operation in the event of exceeding the limit state of the motorcycle in terms of transverse stability. They are individually placed on the sides of the motorcycle.
The use of the system is for the purpose of enhancing the skills of the rider for the purpose of becoming accustomed to the motorcycle. The rider will check the limit of the motorcycle without harmful consequences and thus gain important experience for safe movement on the road. In this way, it is possible to increase road safety indirectly. The paper aims to implement an initial design of a system enabling to change the adhesive conditions of a motorcycle so that when driving on an asphalt surface, it would allow simulating driving on a surface with reduced adhesion, such as wet asphalt.
KEY WORDS: *motorcycle frames, tires, adhesion, SkidMotorbike*

1. Introduction

With the growing number of road vehicles, current cities face the problem of limited parking options. At the same time, car occupancy is very low, averaging 1.8 people per car [6, 15]. One of the possible solutions is to use motorcycles as a means of transport. Along with the improving economic situation, many people buy a motorcycle as a means of spending free time. Motorcycle manufacturers address this trend by investing an increasing amount of money on the development of two-wheeled vehicles [4]. Despite this fact, it is still necessary to pay attention to the area of increasing the safety of these road users. After pedestrians and cyclists, motorcyclists are another group of the most endangered road users. The safety of two-wheeled vehicles can be enhanced by innovating the materials, construction, and implementation of new electronic systems [3, 5]. The second option is to increase the driving skills of motorcyclists. Both of the options should be initially implemented under conditions outside real road traffic [10, 12]. Electronic systems can be developed in laboratories and virtual reality, and subsequently tested. Driving skills can be improved on simulators. This is basically a model of reality [7, 8], which is more or less different from it. Therefore, this article discusses the possibility of increasing the ability of motorcyclists to control their machines. Excessive speed is a critical element that leads to the most common causes of a motorcycle accident. Due to the high speed and inexperience of the driver, the limit of stability of the motorcycle is exceeded, resulting in a skid. Skidding very often leads to a fall with an injury, at best only with damage to property. In many cases, experienced motorcyclists can prevent the fall in a marginal situation by timely and adequate intervention in the steering of the motorcycle. For the driver to intervene in time and to the correct extent, it is necessary to have maximum experience with the driving of the motorcycle.

Due to the initial design of the new system, we will use model conditions. The change of the adhesion force can be realized by reducing the coefficient of adhesion by using special tires [1, 2] or a special surface [11, 14]. The second option for reducing the adhesion force between the motorcycle wheel and the road is to reduce the radial reaction on the motorcycle wheels. This reduction can be achieved utilizing a frame with additional wheels as used in road vehicles [6, 13].

The SkidMotorbike subframe is an additional device that is intended for retrofitting to a motorcycle. The device makes it possible to reduce the radial reaction on a motorcycle wheel. From this principle, the wheels of the motorcycle can transmit a smaller maximum longitudinal and transverse force in contact between the tire and the road. Thus, the motorcycle reaches the limit of adhesion sooner at a lower, so-called safe speed. The SkidMotorcycle system allows changing the adhesion force, according to current requirements, even while riding the motorcycle. With the SkidMotorcycle frame, riders can learn from the very beginnings about motorcycle control to simulations of more demanding maneuvers without damaging the motorcycle or significantly endangering their health.

The paper proposes a design of an additional sliding frame used in a motorcycle. The design was created in the 3D CAD program SolidWorks. The purpose of the SkidMotorcycle frame is to create reduced adhesive conditions so that the motorcycle moves at the limit of stability while going at a safe speed. The primary intention of the frame is to verify the stability of the motorcycle behavior and, at the same time, to have the rider get used to the motorcycle to know how the motorcycle behaves before reaching the limit state without the risk of damage to health or property. The SkidMotorcycle was designed for a motocross motorcycle, KTM 250 SX-F.

2. Materials and Methods

The essence of the change in the adhesion force F_{ad} lies in the reduction of the radial reaction Z_k, transmitted by the motorcycle wheels to the road [6]. This is done using a subframe for the front and rear wheels. When the radial reaction is reduced, the maximum adhesion force transmitted by the motorcycle is reduced, which is given by a simple formula (1), where φ is the coefficient of adhesion.

$$F_{ad} = Z_k \cdot \varphi \,. \tag{1}$$

The transverse skid of the motorcycle was chosen as the limit state. The skid occurs when the transverse force is greater than the lateral force transmitted between the tire and the road [6]. The magnitude of the contact force is given by the vector of the maximum adhesion force. In a double-wheel vehicle, the change of direction is caused not only by turning the steering wheels, as in a four-wheel car but especially by tilting the motorcycle about the axis connecting the front and rear wheels contact surface center of gravity. Therefore, the magnitude of the motorcycle lateral adhesion force when cornering is given by Eq. (2).

$$F_{ad_y} = \left(G \cdot \cos\beta + F_o \cdot \sin\beta\right) \cdot \varphi, \tag{2}$$

where F_{ad_y} – side force; F_o – centrifugal force, G – gravity of the vehicle; φ – coefficient of adhesion; β – slant slope of motorcycle.

Before designing the construction of the sliding frame, the basic dimensions of the motorcycle, which are necessary in terms of clamping to individual parts of the motorcycle and possible spatial arrangement of the SkidMotorcycle, were first established. The basis was the track width, front and rear wheels dimensions, wheel axles dimensions, motorcycle frame size, swingarm dimensions, and front shock absorbers. Subsequently, the motorcycle model was assembled. The motorcycle frame was modeled in a simplified form with a primary emphasis on the location of the sliding frame anchor points to the motorcycle frame. The resulting model of the motorcycle key parts can be seen in Fig. 1.

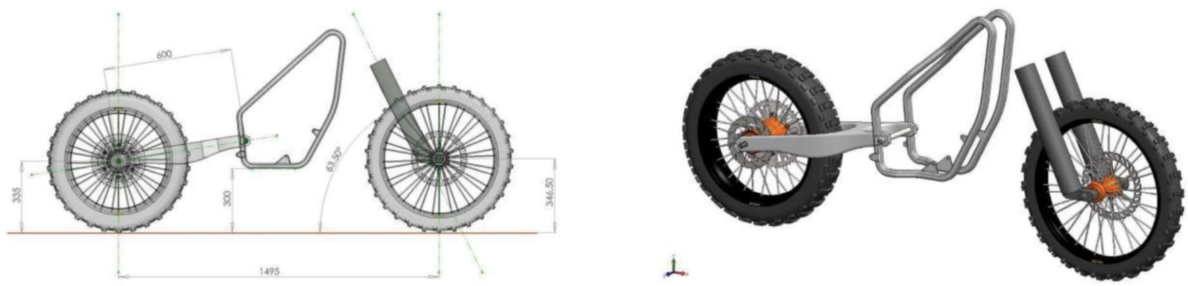

Fig. 1 Simplified model of a motorcycle concept

3. Results and Discussion

The slide frame consists of two separate parts for the front and rear motorcycle wheel. Each of these parts is formed by an upper and a lower part of the frame.

The first point of the design was to clamp and secure the slide frame to the front part of the motorcycle. The front part of the frame is connected to the wheel via an axle, which is inserted into the articulated heads locked with nuts. This solution was chosen because the frame is welded, and these heads will ensure the easy assembly of the frame. The upper arm weldment (Fig. 2) consists of a main tube and side U-profiles with welded plates. Articulated heads are clamped on these plates. For connection to the lower arm, eyes clamps are welded to the main tube, from the front to the tilt assembly, from the rear to the attachment of the hydraulic cylinder.

The lower arm (Fig. 3) is also a weldment, to which the support castors are then attached. It consists of a main lower tube to which the left and right side arms are welded. The front and rear plates are further welded to this skeleton. For connection to the upper arm, the tilt assembly mounts are welded to the sheets.

To connect the upper and lower arms, a tilt assembly, allowing the motorcycle to tilt when cornering, was designed. In the front part, both arms are connected with this assembly; a hydraulic cylinder is inserted in the rear part, allowing the setting of the required adhesion motorcycle conditions.

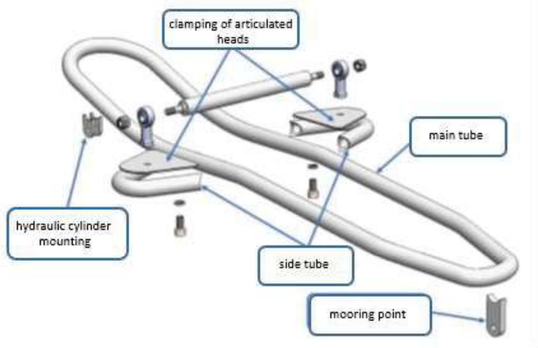

Fig. 2 Upper part of the frame

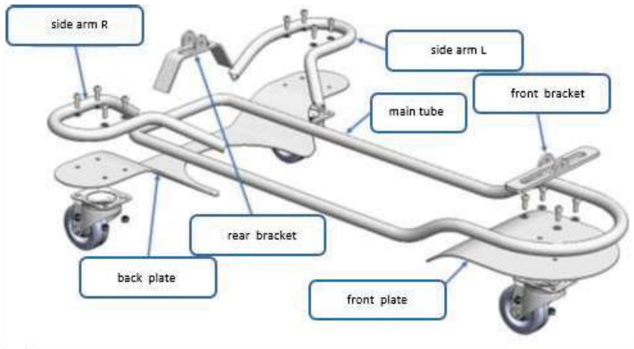

Fig. 3 Lower part of the frame

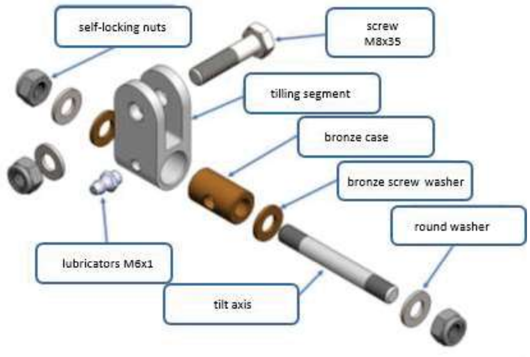

Fig. 4 Tilting element

Fig. 5 Front wheel frame assembly

The tilting element (Fig. 4) consists of a tilting segment into which a bronze housing is inserted. A lubricator was used to ensure trouble-free operation and sufficient service life. A tilt axis is inserted through this housing to get attached to the tilt assembly mount. The whole assembly is connected to the upper arm using a screw connection.

The rear wheel frame is designed according to a similar scheme as used in the front frame (Fig. 5). The rear frame assembly is shown in Fig. 6. The reason for the similarity of the front and the rear frame is the optimization of production costs in terms of materials used and also the assembly of individual parts. The aim was to minimize the number and variety of components of which the frame consists.

Fig. 6 Rear wheel frame assembly

The fall stabilizer arms are used to change the maximum inclination of the motorcycle and the subsequent capture of a possible fall of the rider together with the motorcycle due to exceeding the limit of stability. These arms are attached to the motorcycle frame and allow the setting of the required side tilt angle from 35° for beginners to 50° for experienced riders.

During the construction of the arm, sufficient support and possible adjustment of the tilting angle had to be ensured. The arm consists of a weldment with inserted bronze housings in its lower part to ensure smooth movement when changing the tilting angle setting. Mounting axes are inserted through these housings. Furthermore, a rotating wheel and a telescopic bar are attached in the front part, enabling to change the motorcycle tilting angle. The change in the motorcycle tilting angle size is adjustable according to the current riding situation and the abilities of the motorcyclist. The current design of the stabilizer arm is shown in Fig. 7.

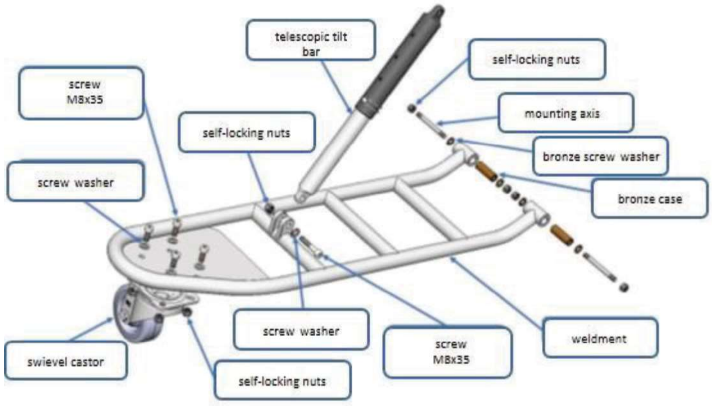

Fig. 7 Drop support arm

For attachment to the lower part of the motorcycle, a plate under the motor was designed, to which the eyes clamps are subsequently welded for attachment to the motorcycle frame and attachment of the fall stabilizer arms. The plate is mounted to the holes in the motorcycle frame with screws.

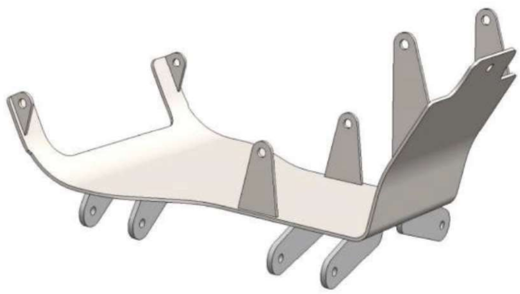

Fig. 8 Plate located under the motor

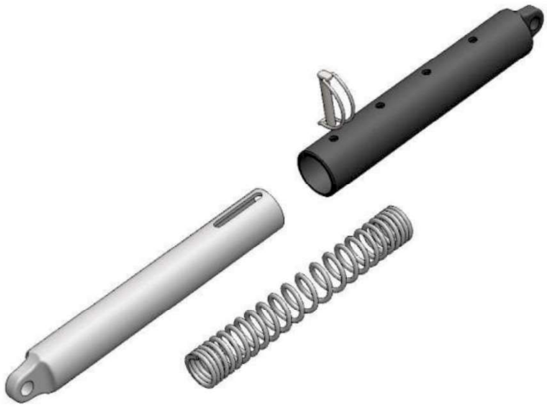

Fig. 9 Damping telescopic bar

The assembly of the middle part of the sliding frame and fall-protecting frame consists of clamping elements to the motorcycle frame and two fall stabilizer arms. The range of change in the setting of the angle of the SkidMotorbik fall stabilizer arms for the minimum and maximum motorcycle side tilting angle is shown in Fig. 10.

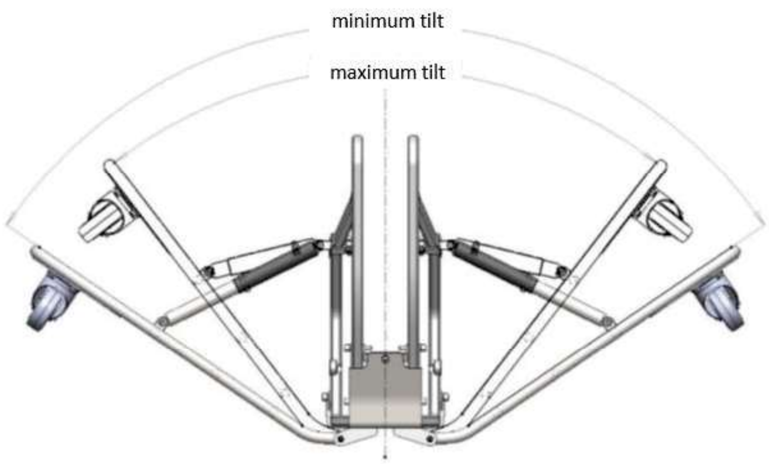

Fig. 10 Arm adjustment range

Since the SkidMotorcycle frame is sufficiently rigid, the magnitude of the impact that is transferred to the motorcycle when the fall stabilizer arm comes into contact with the road is given by the radial flexibility of the tires of the additional wheels. The deformation characteristics of the support unit tires were determined on a static adhesor, see Fig. 11. The data was obtained based on a gradual loading with a vertical force. At a specific load, the magnitude of the radial deformation was subtracted from the position of the static adhesor arm. The deformation characteristic is evident in Fig. 12 and is described according to (3) on the confidence interval $R^2 = 0,9996$. Due to the rolling of the additional ASC wheels, there is an increase in the emitted noise, which is described in more detail in [9].

$$y = -0.3441x^2 + 5.8352x \,. \tag{3}$$

Fig. 11 Deformation of the support wheels on the static adhesor

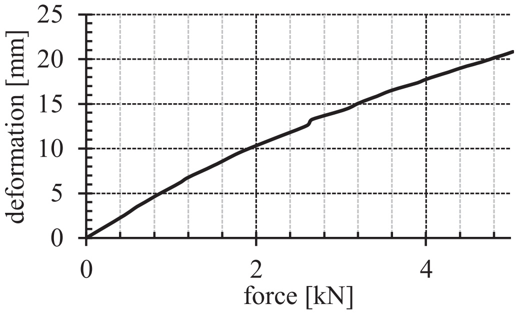

Fig. 12 Deformation characteristics of the wheel units of the Alternative SkidMotorcycle

When riding and exceeding the limit of stability, the fall stabilizer arms come into contact with the bar when the motorcycle reaches the marginal tilting angle. To eliminate the initial shock, a damping element was inserted into the telescopic bar housing. The construction consists of inserting a compression spring into the cavity in the inner tube of the telescopic bar. The inner tube has a modified hole in the shape of a longitudinal groove into which is secured with a locking tube pin. If the wheel rests on the road surface, this construction allows the inner tube to move towards the outer tube. The inserted spring is then compressed, dampening the shock (Fig. 9).

The change in adhesion force is solved using a pair of hydraulic cylinders. The stroke of the cylinders is determined by the pressure fluid and according to the position of the motorcycle wheels, under the load of one standard person until the moment of disengagement of the wheels from the pad. For the given motorcycle, this stroke is 20 mm for both the front and rear wheels. Additional ABS hydraulic units will be used as a source of fluid pressure for the hydraulic cylinders.

The resulting unit of the designed sliding and fall stabilizer frame systems called SkidMotorbike consists of a front-wheel frame, rear-wheel frame, fall stabilizer arms, and a hydraulic circuit. The total weight at maximum use of aluminum alloys is 52 kg.

Fig. 13 Mechanical part of the SkidMotorbike system

4. Conclusions

This paper presents the design of a sliding and fall stabilizer frame for the type of motorcycle specified above. The first step was to map the technical and dimensional parameters of the motorcycle. Subsequently, the arrangement of individual frames according to the identified parameters, was outlined. To design the SkidMotorbik system, the 3D software was used. The design solution of individual components was proposed concerning the availability of materials and the simplicity of production. The aim was the applicability of the system to other motorcycles after minor modifications. To change the adhesion conditions, the frame was equipped with a pair of hydraulic cylinders. For controlling the dynamic stroke according to the driving conditions, the SkidMotorbike system is also equipped with accelerometers together with electronic control for the correct function of these cylinders. Preparations are currently underway for manufacturing a prototype. In addition to teaching motorcyclists, the use of the SkidMotorcycle system can also be used for the needs of research and to compare the theoretical outputs from the models [16] with the real reduced adhesion. More detailed monitoring of the SkidMotorcycle system behavior is subjected to further research.

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