ANALYSIS OF ACCIDENT EVENT – AGRICULTURAL MACHINE AND MOTORCYCLIST

Ludmila Macurova, Pavol Kohut, Miroslav Redl, Michal Ballay
University of Zilina, Slovakia
ludmila.macurova@uzvv.uniza.sk, pavol.kohut@uzvv.uniza.sk,
miro.redl@gmail.com, michal.ballay@uniza.sk

Abstract. During the harvest of agricultural crops, the number of tractors, harvesters and other agricultural machines on roads increases. Collision situations of agricultural machines and road vehicles occur most often. In the event of a collision between agricultural machines and more vulnerable road users, the consequences are more serious. For motorcyclists, the collision situation is much more dangerous and there is a greater likelihood of serious injury or death. According to expert evidence and the crash test results show that if, for example, a motorcyclist collides with a tractor at speeds higher than 80 $km \cdot h^{-1}$, the probability of survival is minimal. The most frequent collision situations are intersections, exits from the side road to the main road, exits from the main road to the side road, confusing turns. The paper deals with the analysis of an accident event of an agricultural machine (self-propelled harvester) and a motorcyclist at a left-hand turn, in the outskirts of the village. The origin is investigated and the course of the accident scene with reference to the resulting specifics from the movement of special agricultural machines on roads. The speed of the vehicles is assessed as part of the analysis before the collision, impact speed with regard to the drivers' visibility and driving technique are evaluated and the established technical cause of the accident event. At the end, the possibilities of averting an accident on the part of individual road users are described.

Keywords: analysis, accident event, agricultural machine, motorcyclist.

Introduction

The operation of agricultural machinery on roads is influenced by the seasonal nature of agricultural activities. These vehicles are generally heavier, wider, and slower than other road vehicles, thus having a significant impact on the traffic network and posing a safety risk. [1] Within the countries of the European Union and the developed powers, accidents involving agricultural machinery are rare compared to accidents characteristic of other vehicles, but their severity is significantly higher. According to the available studies, the majority of accidents were caused by the drivers of agricultural machinery (in China they accounted for up to 96%), but some accidents were caused by other factors (poor road conditions, disregard for road traffic rules, obsolete vehicle equipment, vegetation blocking visibility, wild animals and livestock, etc.). Drivers of non-agricultural vehicles were 5 times more likely to be injured than drivers of agricultural vehicles. Most studies also agree on the absence of a reliable database of agricultural vehicle accidents, which often leads to an underestimation of the importance of prevention, education, creation, and modification of legal standards [2-5].

Traffic collisions between agricultural machinery and the most vulnerable road users are specific compared to other types of traffic accidents that these collisions are much more likely to cause serious injuries (given their nature and extent), very often with fatal consequences. Compared to other road vehicles, agricultural machinery has a much greater number of injurious parts. In a collision between a vehicle and a farm machine, bystanders are much less vulnerable than a motorcyclist because they are not in direct contact with the farm machine and can be effectively protected with the vehicle's safety systems [6; 7].

The mentioned article deals with the analysis of a specific traffic accident involving a motorcycle (SUZUKI brand, SV 650) and an agricultural machine (a self-propelled harvester, John Deere 7380 ProDrive brand), which dimensions (especially width) exceed the largest permissible dimensions established in the legislation of the Slovak Republic. According to the Regulation of the Slovak Government No. 349/2009 Coll. on the largest allowed dimensions and weights of vehicles and driving sets, other technical requirements for these vehicles and driving sets and their marking, the largest permissible vehicle width of 3m for category T4.2 – especially wide tractors is determined [8]. The agricultural machine in question had a width of 3.44 m. It was this oversized width that played a negative role in the occurrence of the accident in question.

Traffic accident analysis

The traffic accident between a motorcycle and an agricultural machine occurred in the early evening on road III class, in the extra-villa section of the village, in the area of a left-turn bend, where the visibility conditions were reduced due to the vegetation located along the road. The agricultural machine moved without an accompanying vehicle, with the working part of the machine in a transport configuration. A motorcycle was moving in the opposite lane of the agricultural machine. The motorcyclist, during the moment of recognizing the character of the agricultural machine, and its overall width (extending into his lane), reacted with a startle effect and subsequent intensive braking. During intensive braking, the motorcycle lost its directional stability, crossed into the opposite lane, and then fell onto the road. At the time of the collision, the motorcycle was sliding on the road with its right side. First, the left front wheel of the agricultural machine ran over the motorcycle and then over its left rear wheel, as a result of which the kinetic energy of the motorcycle was converted into deformational energy, which caused that the motorcycle stopped. The motorcyclist's body was pushed by the left front wheel of the agricultural machine towards the final position. On the place of the traffic accident, the motorcyclist died in result of severe injuries (the immediate cause of death was extensive combined crushing injuries to several organ systems of the motorcyclist's body) [9].

After the collision, there were specific braking conditions for the agricultural machine. Under the left front wheel was the body of the motorcyclist, which left a trail of motorcyclist fibre on the road. Applying this trace to the road caused a decrease in the adhesion conditions between the wheel and the road. Despite the reduction of adhesion conditions, the agricultural machine did not turn to the right due to the asymmetry of braking. The turning of this machine to the right only happened in the section, when the right wheel left the road, and went into the ditch. The following pictures show a view of the place after the traffic accident from the direction of the motorcyclist (Fig. 1), where the brake mark from the wheel of the motorcycle is shown – blue arrow) and a view from the direction of the agricultural machine (Fig. 2), where the brake mark is shown from the agricultural machine – red arrow).

Fig. 1. **View from the motorcyclist's driving direction [9]**

Fig. 2. **View from the driving direction of the agricultural machine [9]**

Including the additional measurement of the braking deceleration of the agricultural machine with reduced adhesion conditions, it was found that when it is intensively braked with both wheels, significant traces are left on the road after the wheels are locked, while the average value of the braking deceleration reaches a value of approx. 5.9 $m \cdot s^{-2}$. During intensive braking of the agricultural machine on the road with reduced adhesion conditions, the value of braking deceleration reached approx. 2.9 $m \cdot s^{-2}$, and the inlet time of the braking effect was approx. 0.2 s.

After considering the fact, that during the measurement there was considerable tilting of the agricultural machine (which caused additional inaccuracy of the measured values of the instantaneous deceleration), it was necessary to reduce the measured mean value of the deceleration by approx. 0.2 $m \cdot s^{-2}$. Therefore, the deceleration value of the agricultural machine after the collision at the level of 2.7 $m \cdot s^{-2}$ was used to calculate during the road accident. Considering the deceleration value of the agricultural machine after the collision, the location of the collision, the final position of the agricultural machine and the assumption, that the driver of this machine started to brake at approximately the moment of the collision, it was calculated, that the impact speed of the agricultural machine was approximately 30 $km \cdot h^{-1}$.

In this case it is very problematic to calculate the impact speed of the motorcycle on the left front wheel of the agricultural machine. The motorcycle was loaded by a very specific mechanism when it was compressed by the wheel of the agricultural machine and the road. With this mechanism, similar damage occurs on the motorcycle as with a relatively large range of impact speed of the motorcycle [7; 10]. As a result of the mentioned effect, it is not possible to calculate the impact speed of the motorcycle with acceptable accuracy, as it is a relatively large range of the impact speed of the motorcycle from 40 km·h^{-1} to 70 km·h^{-1}.

The energetically equivalent speed (EES) of a motorcycle of approx. 59 km·h^{-1} corresponds to an impact speed of 40 km·h^{-1} and EES of a motorcycle of approx. 84 km·h^{-1} corresponds to an impact speed of 70 km·h^{-1} (assuming EES of an agricultural machine of 0 km·h^{-1} and its impact speed of 30 km·h^{-1}), see Fig. 3.

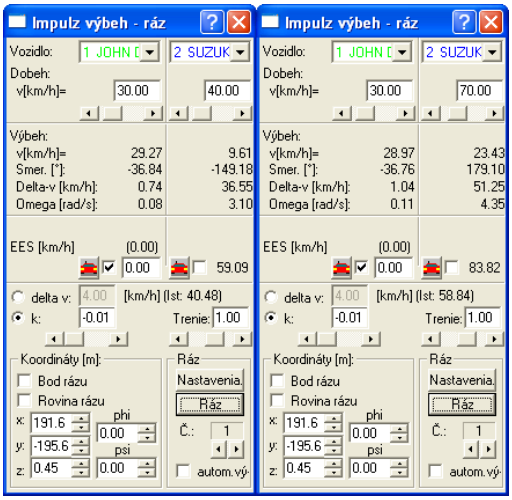

Fig. 3. **Parameters of crash of an agricultural machine and a motorcycle [11]**

Based on the evaluated value of the impact speed of the motorcycle (in the range from 40 km·h^{-1} to 70 km·h^{-1}) and other input values (the length of the section of the motorcycle sliding on the road, the length of the section of intensive braking of the motorcycle, the range of deceleration of the motorcycle) the movement of the motorcycle was calculated before the collision [12]. The individual calculations show that at the beginning of the accident, the motorcyclist was moving at a speed ranging from 61 km·h^{-1} to 90 km·h^{-1}, see Fig. 4.

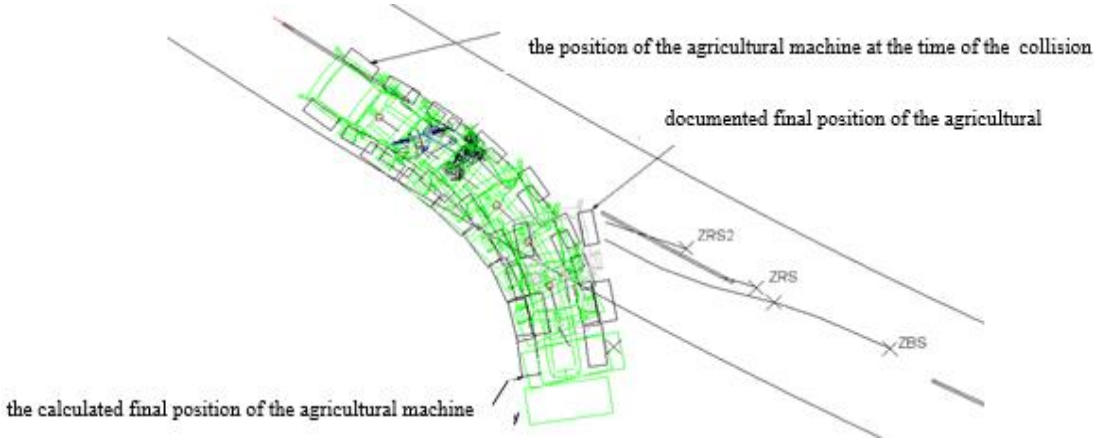

Fig. 4. **Representation of the movement of the agricultural machine from the moment of collision to stopping in the final position [11]**

Evaluation of drivers' driving technique

The driver of the motorcycle was moving in the area of road accident at a speed ranging from 61 km·h^{-1} to 90 km·h^{-1}. After recognizing the collision situation (agricultural machine interfering with the

opposite traffic lane), he reacted by reducing the tilt of the motorcycle (thereby preventing the intensive braking maneuverer) and used intensive braking.

Fig. 5 (left) shows the approximate situation at the moment when the motorcyclist can see for the first time that another road user is moving in the opposite lane. At this moment, the motorcyclist could not recognize that the agricultural machine was encroaching in the opposite lane with its left machine part. This fact was recognizable only when the motorcyclist had a view of the entire width of the agricultural machine (Fig. 5 on the right).

Fig. 5. **View from the motorcyclist's driving direction** [9]

At the moment when the motorcyclist was able to recognize that the agricultural machine was encroaching into the opposite lane, the width conditions on the road were such that a corridor of approx. 2.4 m remained for the motorcyclist to drive (the agricultural machine was encroaching into the opposite lane by approx. 0.6 m). About 2.7 seconds remained until the moment of collision (with the motorcyclist moving at an average speed of 75.5 $km \cdot h^{-1}$). When the motorcyclist was driving approximately in the middle of his lane, such situation happened, with the same constant driving of the agricultural machine and the motorcycle (in the same transverse position as at the beginning of the accident scene), where it would not be possible for them to pass safely.

From a technical point of view, it is very likely, that the motorcyclist reacted to the given situation with the startle effect, which means that a very short time remains to pass for the agricultural machine and the motorcycle (2.4 s assuming that the motorcyclist was moving at a speed of 75 $km \cdot h^{-1}$ and the agricultural machine at 31 $km \cdot h^{-1}$). If we subtract 1s to 1.2s of the motorcyclist's reaction time from the specified time, we get that the motorcyclist had about 1.2s to 1.4s left to pass after a moment of fumbling with the agricultural machine (after the reaction time). According to the given data, it can be concluded that due to the movement of the agricultural machine about 0.6 m behind the centre of the road, a collision situation for the motorcyclist occurred. To eliminate the collision situation (after the reaction time of the motorcyclist) the motorcyclist had about 1.2 to 1.4 seconds left (intel contact with the agricultural machine) with an evasive maneuverer to the right. This maneuverer was feasible, but it required a certain riding experience of the motorcyclist and was conditioned by the fact that there would be no startle effect [6].

After recognizing the collision situation, the motorcyclist did not choose an evasive maneuverer to the right but braked intensively. When intensively breaking a motorcycle in a corner, it is usually preceded by a maneuverer to reduce the tilt of the motorcycle, as a result of which the motorcycle stops following the right edge of the road and moves into the opposite lane. The following can also occur as a result of the counter steering effect, which can occur precisely in the above situation with the effect of being startled. As a result of the intensive braking of the motorcycle, the rear wheel of the motorcycle was blocked, directional instability occurred, and the motorcyclist fell [7; 10]. Subsequently, the motorcyclist with his motorcycle slided on the road until he hit the left front wheel of the agricultural machine.

The driver of the agricultural machine was moving in the mentioned section with a lane width of 3.05 m and partially encroached into the oncoming lane, approximately 0.6 m wide. With normal driving technique (approx. 25 cm from the right edge of the road), this driver did not have the option not to intervene beyond the geometric centre of the road. Due to the width of the agricultural machine (approx. 3.44 m), and when driving through the corner section with reduced visibility ratios, a collision situation occurred for oncoming drivers, driving even with the correct driving technique. According to the Regulation of the Government of the Slovak Republic No. 349/2009 Coll. (cited at the beginning of the

article) the agricultural machine exceeded the maximum allowed width [8]. Pursuant to the decree of the Ministry of Transport and Construction of the Slovak Republic No. 464/2009 Coll., which establishes the details of the operation of vehicles in traffic on land roads, it was necessary for driving of agricultural machine to be accompanied by accompanying vehicles [13].

Assessment of the possibilities of avoiding a collision by the drivers

According to the results of the assessment of the driving technique of the driver of the agricultural machine and the individual simulations, it can be concluded that the driver had the opportunity to avoid the occurrence of the traffic accident, if he drove in such a way that he did not interfere with the oncoming traffic lane. In this case, however, he would have to move with his right wheels partially outside the roadway, namely approx. 0.4 m. From a technical point of view, however, it cannot be ruled out that the traffic accident would not occur even with the mentioned driving technique of the driver of the agricultural machine. Another option to avoid the occurrence of the traffic accident by the driver of an agricultural machine would be driving that meets the conditions of driving oversized loads, and driving with accompanying vehicles.

According to the results of the assessment of the motorcyclist's riding technique and the individual simulations performed, it can be concluded that the motorcyclist had the opportunity to avoid the occurrence of the traffic accident, if he did not start reacting to the collision situation with a startle effect, by reducing the tilting of the motorcycle, and by intensive braking, but he instead performed an avoidance maneuverer on the right. The possibilities of the avoidance maneuverer (right) by the motorcyclist had to be assessed separately for the lower limit of the motorcycle speed (61 $km \cdot h^{-1}$), for the upper limit of the motorcycle speed (90 $km \cdot h^{-1}$), and for the average speed of the motorcycle (75 $km \cdot h^{-1}$) at the beginning of the accident.

At the lower speed limit of the motorcycle (61 $km \cdot h^{-1}$), the motorcyclist had the opportunity to recognize for the first time, that another road user was moving in the opposite direction, approx. 93 m between the motorcycle and the agricultural machine. At the speed of the motorcycle (61 $km \cdot h^{-1}$) and the agricultural machine (31 $km \cdot h^{-1}$), approx. 3.6 seconds remained to pass after the moment of their contact. The motorcyclist's ability to recognize that the agricultural machine was encroaching on the oncoming lane was approx. 77m in the mutual distance between the motorcycle and the agricultural machine. After the moment of their contact, about 3 seconds remained to pass. At this moment, the motorcyclist had sufficient time and distance to avoid the collision situation with the correct driving technique.

At the upper speed limit of the motorcycle (90 $km \cdot h^{-1}$), the motorcyclist had the opportunity to recognize for the first time, that another road user was moving in the opposite direction, approx. 90 m between the motorcycle and the agricultural machine. At the speed of the motorcycle (61 $km \cdot h^{-1}$) and the agricultural machine (31 $km \cdot h^{-1}$), approx. 2.7 seconds remained to pass after the moment of their contact. The possibility for the motorcyclist to recognize that the agricultural machine was encroaching on the oncoming lane was approximately 74m in the mutual distance between the motorcycle and the agricultural machine. After this moment, about 2.2 seconds remained to elapse. At this moment, the motorcyclist had a relatively short time and distance to avoid the collision situation.

At the middle speed limit of the motorcycle (75.5 $km \cdot h^{-1}$), the motorcyclist had the opportunity for the first time to recognize that another road user was moving in the opposite direction, approx. 91 m between the motorcycle and the agricultural machine. At the speed of the motorcycle (61 $km \cdot h^{-1}$) and the agricultural machine (31 $km \cdot h^{-1}$), approx. 3.1 seconds remained to pass after the moment of their contact. The motorcyclist's ability to recognize that the agricultural machine was encroaching on the oncoming lane was approximately 72m in the mutual distance between the motorcycle and the agricultural machine. After the moment of their contact, about 2.5 seconds remained to pass. At this moment, the motorcyclist had a relatively short time and distance available to avoid the collision situation with the correct driving technique.

Conclusions

Traffic collisions between agricultural machines and the most vulnerable road users occur in various configurations, especially during the harvest of agricultural crops. They most often occur after the failure of the human factor, incorrect estimation of the situation in traffic, and failure to comply with the road

traffic rules [14]. The paper analysed a traffic accident in which an agricultural machine (with the width exceeding into the oncoming lane) and a motorcycle collided in a left-turning curve.

The cause of the accident was the fact that when the motorcyclist was passing on the right-hand bend, due to the creation of a collision situation (on the part of the driver of the agricultural machine), the effect of the motorcyclist getting scared occurred, as a result of which he started to brake intensively, crossed with the motorcycle into the opposite lane, where the collision with the agricultural machine occurred. After the collision, the specific braking conditions of the agricultural machine occurred, where the value of the braking deceleration was about 2.9 $m \cdot s^{-2}$ and the time of the braking effect build-up was about 0.2 s. The calculated impact velocity of the agricultural machine into the motorcycle was about 30 $km \cdot h^{-1}$. The individual calculations show that the motorcyclist was travelling at speeds ranging from 61 $km \cdot h^{-1}$ to 90 $km \cdot h^{-1}$. The impact speed of the motorcycle was difficult to calculate (this is a relatively large speed range due to the stresses on the motorcycle from a very specific mechanism). The driver of the agricultural machine could have avoided the accident if he had not intervened in the oncoming lane when driving (he would have had to move about 0.4 m with his right wheels off the road), or if his driving had been complemented by accompanying vehicles. At the calculated speed of the motorcycle ($61 km \cdot h^{-1}$), the motorcyclist would have had sufficient time and distance to avoid a collision situation with correct driving technique. At higher motorcycle speeds, the motorcyclist would have a relatively short time and distance to avert the collision situation. To eliminate the collision situation, the motorcyclist could have performed an evasive manoeuvre at that moment, but this required riding experience and the effect of being overawed could not have occurred.

In regards with the analysis of a specific traffic accident involving an agricultural machine and a motorcycle, it can be concluded that in order to effectively minimize traffic accidents and their consequences, it is necessary to pay close attention to important aspects, especially road users and agricultural machines moving on roads.

Author contributions

Conceptualization, M.R. and P.K., methodology, Ľ.M., software, P.K. and M.R., formal analysis, Ľ.M. and M.B., data curation, Ľ.M. and M.B., writing – original draft preparation, Ľ.M. and M.B., writing – review and editing, P.K. and M.R., visualization, M.B., project administration, Ľ.M., funding acquisition, P.K. All authors have read and agreed to the published version of the manuscript.

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