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Editorial:
IN MEMORY OF AYRTON SENNA
the World's Greatest F1 Driver

Prof. Enrico Lorenzini

Universita' Alma Mater Bologna, Bologna 40126, Italy

Corresponding Author Email: enrico.lorenzini@unibo.it; prof.enrico.lorenzini01@gmail.com

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1. INTRODUCTION

<<Ayrton Senna is universally known as "Magic," a nickname born from his incredible driving skills, especially in the rain and in qualifying. Considered one of the greatest drivers and sportsmen of all time, he is seen as an icon of courage, determination, and pure talent.>>

Today marks the anniversary of his death, which occurred on May 1, 1994, during the San Marino Grand Prix at the Autodromo Enzo e Dino Ferrari.

His car went off track at the Tamburello curve and crashed into a wall at over 200 km/h.

He died of serious head injuries shortly after being admitted to the hospital. Significant consequences: Senna's death led to a revolution in F1 safety, with profound changes to the tracks and cars.

These days, a director and a Canadian "crew" <<Troupe>>are seeking to shed light on the event and are interviewing many key figures from the time, as well as new scholars who wish to contribute.

This opportunity is also being offered to me, I was President and leader of the technical Commission of investigation of the Court and so I will briefly present my reconstruction of this event, seen from a truly privileged perspective. I will not attempt to compile a bibliography of what claims to be simply a brief, correct piece of information for 'everyone', which goes back to the original sources, experienced first-hand. Finally, a sad, affectionate farewell to FORGHIERI and Carletti, who

shared this 'great toil' with me. In the past, many asked me to write a 'book' with them, but I never agreed. In this long period, that is, since the closing of the first appeal, I have only written two articles: first, one might define as an informative interview, in <<Newsweek>> Magazine, then 10 million copies, today 7/8, in which the drama was at the centre of the issue and the second subsequently in <<Der Sachverstaendige>>, a German-language magazine, by Enrico Lorenzini, Gp Cammarota, (my colleague) and Dr. H. Herold (a German technician).

2. INVESTIGATION BY THE BOLOGNA PROSECUTOR's OFFICE [PROSECUTOR GENERAL DR. GINO P. LATINI]

In Italy, given the death at a public event, an investigation for manslaughter was opened. The technical investigations and findings were coordinated by the Bologna Prosecutor's Office, under Deputy Prosecutor M. Passarini, and as President - Leader - of TECHNICAL COMMISSION investigating Senna's death, was appointed by the Court, prof. Enrico Lorenzini and with the involvement of the traffic Police. The legal proceedings lasted over a decade, with various levels of adjudication. The final outcome (Cassation, 2007).

The Italian Courts established that:

The cause of the accident was the failure of the steering column.

The failure was the result of a defective and poorly executed design modification.

However, the criminal charges did not lead to definitive convictions due to statutes of limitations or acquittals.

The initial technical commission appointed by the Prosecutor's Office consisted of Lorenzini, Forghieri, and Carletti.

The role of Professor Enrico Lorenzini: He is a central figure on the technical-scientific level, a university professor and Dean of the Faculty of Engineering at the University of Bologna. He was appointed as an expert/technical consultant and Chairman of the Technical Committee as part of the investigation. His main contribution: His team prepared a technical report of approximately 600 pages, which concluded:

<<The steering column had been cut and welded to adapt the driving position>> and, unfortunately, the weld showed:

- Structural defects
- Signs of hasty work
- Stress concentration points

It was **Professor Lorenzini who first saw the above in person during the initial inspection**, and he was included in that first report, because he himself said [getting carried away by emotion] while brandishing the two mechanical parts,

that this was the cause of such a dramatic accident, and one experienced as such by everyone.

The subsequent analysis states that the component was already weakened and close to failure, and failed just before the curve, a point that will be revisited.

This analysis was crucial in guiding the entire judicial reconstruction.

Senna did not die due to human error, but rather due to a structural technical problem with the car.

The Italian investigation was long and complex, attracting considerable international media attention.

Professor Lorenzini played a key role in demonstrating and supporting the mechanical failure of the steering system.

3. STEERING COLUMN FAILURE (HISTORY AND INITIAL TECHNICAL ANALYSIS)

Ayrton Senna's car, Williams FW16, featured a crucial modification made just days before the GP.

Why the steering was modified:

Senna was uncomfortable with his driving position. The Williams Grand Prix Engineering team therefore modified the steering column (the rod connecting the steering wheel and steering rack), lengthening it to improve ergonomics and visibility. This modification was not part of the original design.

According to the expert report led by Professor Enrico Lorenzini, the modification was made as follows:

The column was cut, an extension tube was inserted, and the whole thing was rewelded.

The steering column was cut, an extension tube was inserted, and everything was rewelded.

Very visible and detected problems: Suboptimal welding, presence of cracks (microfractures), geometry that created stress concentrations.

4. THE MECHANISM OF FAILURE

During the race:

- The stresses (vibrations + lateral loads) progressively weakened the welded point;
- The component suffered material fatigue until it suddenly broke.

This resulted in a total loss of steering control.

At the Tamburello corner - the dramatic moment - Senna was unable to correct his trajectory and the car went straight into the wall. Senna had immediately heard strange noises, but apparently didn't understand where they were coming from. At first, they said he had even changed a set of tires. He could have stopped during the race, his life was at stake, but he didn't. Why? Hindsight is always 20/20.

5. INVESTIGATIONS AND INSPECTIONS

From the technical reconstructions, it can be said that there was no driving error; unfortunately, the instantaneous and irreversible event that the analyses indicated should have occurred. It should be noted that the expert report's conclusion (later accepted in the trials) holds that the steering column failure occurred before the final impact, which was therefore not the cause**. This is crucial because it distinguishes cause from consequence and shifts responsibility to the design/modification, not the accident itself**.

Technical summary, a very serious point: an order was given, and someone carried it out, to make a custom modification to a critical component, resulting in a structurally weak weld and therefore fatigue failure under load, loss of steering → fatal impact

After the May 1, 1994, accident at the Imola racetrack, the Bologna Public Prosecutor's Office opened a manslaughter investigation, and technical inspections of the car, video analysis, and engineering assessments were conducted (including one coordinated by Professor Enrico Lorenzini).

Several members of the Williams Grand Prix Engineering team were indicted:
Frank Williams (team principal)
Patrick Head
Adrian Newey (designer)
David Brown
The charges concerned alleged responsibility for the design and modification of the steering system.

First Instance (Bologna Court, 1997):
All defendants were acquitted.
Reasoning: the act did not constitute a crime or insufficient evidence of direct criminal liability.

Appeal (2000–2004):

During the appeal, the technical reports were re-examined and the steering column failure was confirmed.

--Patrick Head was found liable, but the offense was deemed time-barred.

--The other defendants were acquitted.

Supreme Court of Cassation (2005–2007)

Final decision (2007):

- Confirmation of technical liability for the steering column failure.
- Confirmation of the statute of limitations for Patrick Head.
-Final acquittal for the other defendants.

Some final data:

- The steering column had been modified (cut and welded);
- The breakage was attributed to manufacturing defects;
- Stress concentration at the welded point;
- The failure occurred before the impact.

Total duration:

Approximately 13 years between the accident and the final conclusion.

- No final enforceable criminal conviction;
- Technical liability for the steering failure was recognized;
- The main crime was extinguished due to the statute of limitations.

6. MAIN CONTROVERSIES AND ALTERNATIVE HYPOTHESES THAT HAVE EMERGED OVER TIME ON SENNA's DEATH

- Loss of grip due to debris (debris)

A few laps before the accident, there had been contact between other cars, and fragments (debris) were present on the track.

- It has been hypothesized that Senna's car: lost grip by running over debris or a dirty area of the racing line.

- Another hypothesis: Lowering of the car (bottoming)

In 1994, active suspension was banned, making the cars more unstable and susceptible to bottoming: The car would have hit the ground violently at Tamburello, causing loss of control.

- Tire problems

Substandard pressure with non-ideal temperatures after the safety car and sudden loss of performance.

- All hypotheses are not indicated as the determining cause

Over the years, subsequent interpretations have emerged with further reconstructions in documentaries and technical articles, and conferences. The following have come to light: a combination of multiple factors (setup, track, tires) and the role of the Williams Grand Prix Engineering car design.

In Summary, alternative hypotheses include debris on the track, set-up and contact with the ground, tire conditions, and the effects of the safety car. However in the legal proceedings, **the central reconstruction remained that of the failure of the modified steering column.**

7. SIMPLE TECHNICAL CONCLUSIONS

Tangential (shear) stresses at the failure point of the steering column of Ayrton Senna's car.

The steering column is subjected primarily to:

1- torsion (when the driver turns the steering wheel);

2- bending (due to vibrations and lateral loads);

3- cyclic dynamic loads (track irregularities);

4- Torsion is directly related to tangential stresses.

Torsional shear stress law:

For a cylindrical shaft: $\tau = Tr/J$

where: τ = shear stress;

T = applied torque;

r = distance from the center;

J = polar moment of inertia of the cross-section.

The stress is maximum on the outer surface, that is, precisely where the cracks begin.

Effect of welding on the stress field.

According to the expert analysis of the commission coordinated by Prof. Enrico Lorenzini, the modification (cutting + welding) introduced:

a) Geometric discontinuity

- local variation in cross-section

- misalignment of the axes
which results in an increase in local stresses.

b) Stress concentration
A stress concentration factor is created at the welded point:

$$\tau max = Kt \cdot \tau nom$$

Kt > 1 (even much higher if the weld is imperfect).
Therefore, the actual stress can be much higher than the ideally calculated one.

c) Metallurgical defects - Prof. Cammarota
Possible effects: inclusions, porosity, microcracks, and these defects act as fracture triggers.

d) Material fatigue
The load was not static but cyclic:
Each revolution → thousands of micro-stresses with alternating torsion and vibration.
The effective shear stress becomes lower than the static limit over time, but sufficient to cause fatigue failure. The typical mechanism is crack initiation, slow propagation, and sudden final failure.

e) Breaking point
In this specific case: The failure occurred at the weld, where the area with maximum shear stress and maximum concentration effect occurs, reaching the critical combination.

torsion + defect + concentration → collapse

f) Mechanical consequence
When the steering column fails, the steering wheel no longer transmits torque and the wheels remain in an uncontrolled position, with immediate loss of control of the vehicle.

Final technical summary:
- The shear stresses were maximum at the surface.
- The welding amplified these stresses.
- The fatigue led to crack propagation.

- The failure was sudden but well-prepared in the time.

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