Journal of the National Academy of Forensic Engineers®

NATIONAL ACADEMY OF FORENSIC ENGINEERS

http://www.nafe.org
ISSN: 2379-3252

Vol. 34 No. 2 December 2017

Forensic Engineering Analysis of a Motorsports Racing Incident

By Stephen D. Knapp, PE (NAFE 891S), Richard M. Ziernicki, PhD, PE (NAFE 308F), and Ben T. Railsback, PE (NAFE 713S)

Abstract

The motorsports racing industry was built on the foundation of people wanting to engage in competition, take risks, and enjoy the capabilities of their go-fast hobbies. Risk undoubtedly accompanies such dangerous activities. As a result, race participants sign a waiver, giving up their right to file claims against organizers of the racing event. Who then is liable for the failure of a component that is certified for racing and is responsible for an injury? This paper will address this question and outline important factors related to an incident involving the failure of a race-certified transmission flexplate that resulted in serious injury.

Keywords

Forensic engineering, racing, standards, failure analysis, certified, certification, flexplate, SFI

Case Study

In July of 2011, a drag racer of a modified pickup truck was racing his vehicle at a local National Hot Rod Association (NHRA)[1] event. Prior to starting the race, the driver was performing a burnout — a procedure where the subject vehicle remains stationary while spinning the vehicle's driven wheels to heat the tires for racing. During the burnout, it was reported that an object came free from the pickup and struck a crew member, causing serious injury. It was later determined that a transmission flexplate counterweight had separated from the vehicle and was found the next day by a track official in the vicinity of the incident. In addition, the racer of the vehicle was able to verify that he had lost the counterweight from the vehicle's flexplate. The racer indicated he had purchased the flexplate only months before the incident, prior to the start of racing season.

Product Discussion

On a vehicle equipped with an automatic transmission, a flexplate is attached between the engine crankshaft and the transmission's torque convertor. A flexplate is similar to a flywheel in a manual transmission engine; it provides a mechanical coupling between the engine's crankshaft and transmission. Depending on the type of engine, some flexplates will have a balance weight attached to them to achieve proper engine rotational balance. During the subject incident, the counterweight separated from the rotating flexplate and exited through an access port located on the bottom of the bellhousing. At the time of the separation, the counterweight had a tangential velocity of approximately 160 mph. The counterweight struck a crew member who was standing beside the vehicle in a restricted area of the race track.

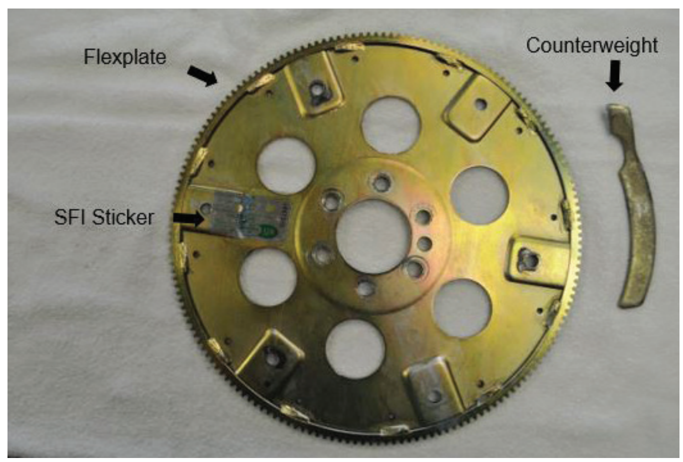

Figure 1
Subject flexplate with separated counterweight.

The subject flexplate (**Figure 1**) includes a stamped steel inner disc with the ring gear and counterweight welded to the inner disc. It was manufactured to work with an externally balanced Chevrolet-based 454 Cubic Inch Displacement (CID) engine. The flexplate was labeled with a SEMA Foundation Inc. (SFI)[2] 29.1 certification sticker.

Stephen D. Knapp, PE, Richard M. Ziernicki, PhD, PE, and Ben T. Railsback, PE, 7185 South Tucson Way, Englewood, CO 80112-3987, 303-925-1900; sknapp@knottlab.com, rziernicki@knottlab.com.

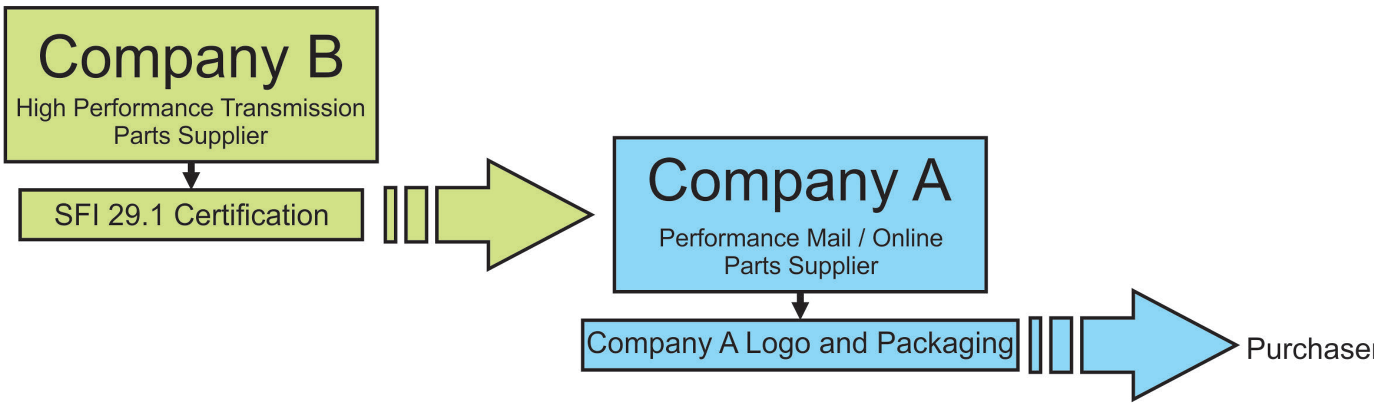

Figure 2
Company A original business model.

SFI 29.1 Overview

The SFI Foundation specification 29.1 "establishes the uniform test procedures and minimum standards for evaluating and determining performance capabilities for Automatic Transmission Flexplates used by individuals engaged in competitive motorsports[3]." During SFI 29.1 testing, the flexplates are spin tested between 12,500 and 13,500 rpm for a duration of one hour, then examined for signs of failure, such as cracks, fractures, weld failures, etc. Upon completion of the spin test, the flexplate is destructively sectioned and cut into metallurgical samples to analyze and test for the minimum yield strength, minimum tensile strength, and percent elongation of the material. These mechanical properties are compared to minimum standards set forth by SFI 29.1. SFI further states, "…logo/designation is in no way an endorsement of certification of product performance or reliability by SFI."

Representative Sample Testing

SFI 29.1 requires a manufacturer to test a single representative product unit every two years. According to SFI: "For a given model, the largest outside diameter with the smallest crankshaft mounting bolt pattern shall be selected[4]." SFI also states: "If all other factors remain the same, a dimensional change in outside diameter or mounting bolt pattern is not considered a model change[5]." Therefore, the SFI certification process does not require testing of individual model flexplates for various different engine configurations — only a representative sample meeting SFI's specific criteria for testing is required. In addition, testing of a flexplate unit without a counterweight (zero balanced) was acceptable to SFI as meeting the criteria necessary to be considered a representative sample.

National Hot Rod Association Rules

The subject incident occurred during an NHRA drag racing event. For a driver and vehicle to be qualified to race in a drag racing event, the driver, necessary safety gear, and vehicle must comply with the rules set forth by the current NHRA Rulebook. With drag racing being an Elapsed Time (ET) event, the rules and regulations set forth by NHRA are based on a vehicle's ET as well as the achieved speed of the vehicle in miles per hour (mph). The quicker and faster a vehicle becomes, the more safety regulations a racer and vehicle will be required to comply with. Many of the NHRA rules specify the use of equipment that complies with SFI specifications. For racers having an ET quicker than 10 seconds in the quarter mile — or faster than 135 mph — a flexplate complying with SFI 29.1 certification becomes required according to NHRA rules. Because the subject race vehicle was slower than 10 seconds ET (had an ET higher than 9.99 seconds), SFI 29.1 flexplate certification was not required on his vehicle.

Manufacturing / Reselling Process

The subject flexplate was purchased by the racer from an online/mail-order high-performance parts distributor (Company A). The heavy-duty flexplates sold by Company A were originally supplied in bulk from a performance transmission parts distributor (Company B) and came complete with an SFI certification sticker. After being received by Company A, the part was packaged with the logo of Company A and put into inventory for sale. A flow chart showing the original business model established by Company A is shown in **Figure 2**.

Later, the business model changed when Company B decided to quit supplying Company A with its flexplates. As a courtesy to Company A, Company B divulged that it had not been manufacturing these parts themselves but rather obtaining these parts from a parts supplier (Company C) and that Company A could continue to be supplied with flexplates from Company C. Company C was willing

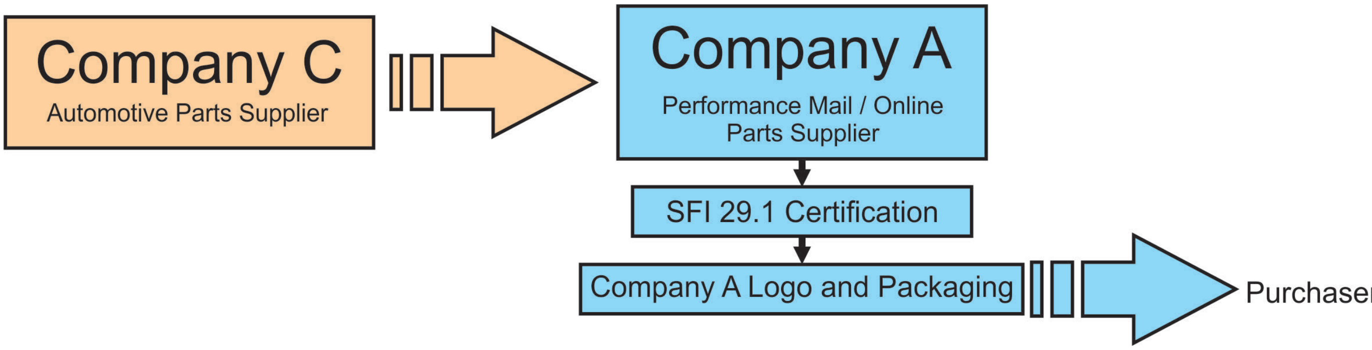

Figure 3
Company A modified business model.

to continue to sell flexplates to Company A, provided that Company A perform its own SFI testing and certification process on the flexplates. To accomplish this, Company A consulted directly with SFI and its test lab to comply with the necessary SFI testing protocols required to continue selling the flexplates as SFI certified. The business model known to Company A at the time of the subject flexplate sale is shown in **Figure 3**.

After the subject incident (and all parties were put on notice), it was discovered that the actual manufacturer of the part was a fourth entity (Company D), which sold its product as a heavy-duty flexplate to Company C. This company contended that the part it manufactured was never intended for the high-performance market. The flow chart of the actual business model that was in place at the time the subject flexplate was sold is shown in **Figure 4**.

Company D reportedly manufactured the subject flexplate and used an automatic wire Metal Inert Gas (MIG) welding machine to weld the ring gear to the inner disc. The counterweights were MIG welded to the flexplate inner disc by hand (manually), rather than using an automated process like the ring gear connection to the disc. As observed in **Figure 1**, the counterweight is detached from the flexplate assembly. Three welds were observed on the subject flexplate steel inner disc in areas that were intended to join the counterweight to the flexplate assembly. However, the welds between the flexplate inner disc and counterweight did not fully join and penetrate the counterweight during the welding process. The lack of weld penetration is clearly visible, as shown in **Figure 5**. It can be seen that between the arrows there is no significant melting consistent with the counterweight having been joined with the flexplate inner disc as a result of the welding process. The lack of penetration, melting, and joining of the two parts is a welding defect known as a “cold weld.” Because the product is coated with a gold-colored anti-corrosion material (zinc dichromate) after welding, certain welding defects, cracks, or disparities would not be visible to those handling the product after it was manufactured by Company D and prior to the counterweight separation.

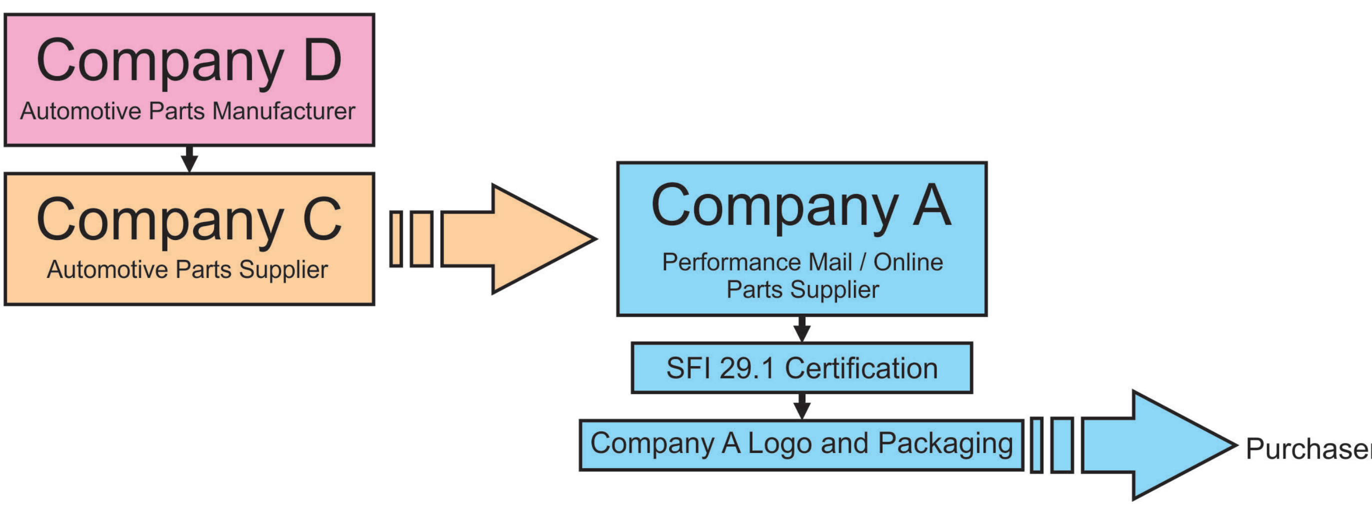

Figure 4
Actual business model at the time of the product sale.

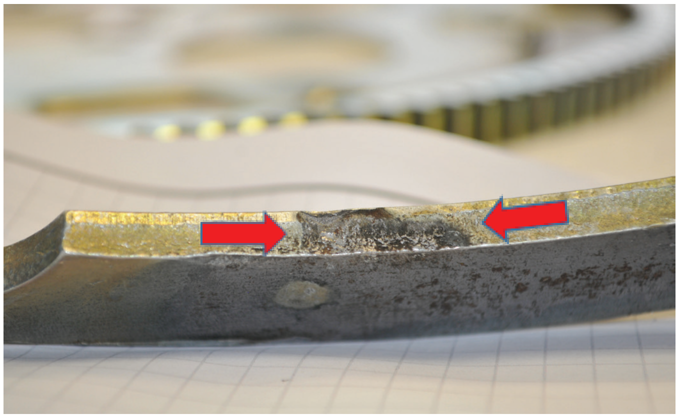

Figure 5
Lack of weld penetration.

Metallurgical analysis consisting of Scanning Electron Microscopy (SEM), sectioning of the counterweight, and metallography further confirmed the lack of weld penetration to the counterweight during the assembly of the flexplate. Metallurgical properties consistent with the machine blank formation of the part were also visible in the area where the weld was attempted. During the stamping process, the counterweight is machine stamped from a sheet of metal under extreme mechanical pressure using a custom die. The pressure initially cuts the materials, but as the process progresses, the remaining stock separates from the stamped sheet metal as a result of high shear forces.

This shearing process creates two very distinct patterns on the edge of the counterweight, as shown in **Figure 6**. The portion of the part that is cut by the die has a clean and smooth edge as highlighted in red text in **Figure 6**. The portion that shears and separates from the stock material has a rough and unfinished surface, as highlighted in blue in **Figure 6**. These characteristics run the length of the edge of the counterweight. Melting of the material due to weld penetration would eliminate these surface characteristics during a proper welding process. However, it can be seen in **Figure 6** that these surface characteristics remain in the area that the counterweight was intended to be welded, and confirms that it lacks weld penetration. Further, the gold coating that is applied after the welding process is visible on the surface of the weld circled in blue in **Figure 6**, indicating that the materials were not joined at the time of the gold coating application.

Figure 6
Failed counterweight and weld — blue area indicates shear region; the red area indicates area cut by die; the gold coating found on the weld bead surface is circled in blue.

Discovery documents indicated that the Company D "heavy-duty" flexplates were supposed to be manufactured with additional welds as its sales literature indicated: "Balancing weights are not only resistance welded but are also MIG welded for better holding power of these weights." However, based on visual examination of the subject counterweight, the process of joining the counterweight to the flexplate with resistance welding was omitted on the subject flexplate.

Company D reported that it did not perform testing of flexplates according to the SFI 29.1 Quality Assurance Specification. In fact, Company D stamped "NON SFI" on the flexplate. Company D also reported that it omitted complying with any industry standards related to the rotational speed capability of its flexplates. Society of Automotive Engineers (SAE) Standard J1456[6] for "Maximum Allowable Rotational Speed for Internal Combustion Engine Flywheels" and SAE Standard J1240[7] "Flywheel Spin Test Procedure" are two automotive industry standards that relate to the quality and capability of flexplates. Under the SAE J1456 standard, a rotational test speed of 13,750 rpm would be required of a Chevrolet 454 engine with a factory maximum recommended rotational speed of 5,500 rpm.

SFI 29.1 Spin Testing of Exemplar Externally Balanced Flexplates

Spin testing was performed with exemplar flexplates using the test requirements of SFI 29.1 and the test configuration as recommended by SAE J1240. The testing was conducted with two exemplar externally balanced flexplates at a spin testing laboratory. Unlike the subject flexplate, the available stock of exemplar flexplate assemblies had counterweights that were both MIG welded and resistance welded to the flexplate assembly. The addition of the resistance welds was a change that was apparently implemented after the subject incident for additional securement of the counterweight. To conduct the test, the

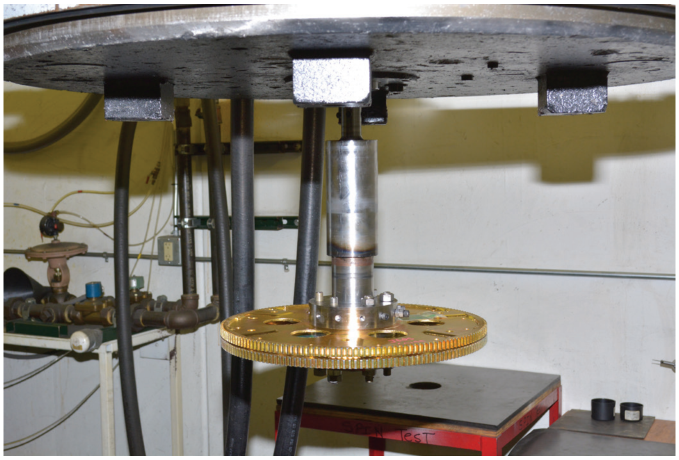

Figure 7
Testing of exemplar externally balanced flexplates.

two exemplar flexplate assemblies were coupled together with a test fixture having their counterweights opposite of each other to make a balanced assembly (**Figure 7**). Spin testing of the exemplar flexplates was conducted above 12,500 rpm for one hour in accordance with SFI 29.1 without failure to either of the flexplate assemblies or attachments of the counterweights.

SFI 29.1 Testing is Destructive

The SFI 29.1 testing protocol is destructive, preventing the tested product from being put into service after testing. Upon completion of the spin testing, the flexplate is cut into sections in order to test the mechanical properties of the flexplate material. This process destroys the flexplate, preventing it from being put into service. Therefore, any individual flexplate having SFI 29.1 certification has not undergone SFI 29.1 testing itself.

Evaluation of Exemplar SFI Certified Flexplates for Chevrolet 454 Engines

The authors examined 12 heavy-duty Chevrolet 454 externally balanced flexplates, each sold under a different brand name. The examination of these externally balanced SFI-approved flexplates shows that the subject flexplate was of virtually the same design and quality of those commercially available on the market. Examination of these flexplates shows that the common industry practice of securing the counterweight to the flexplate assembly is with five to six individual MIG welds encompassing the perimeter of the counterweight. This was different than the subject flexplate that used three relatively small MIG welds for securement of the counterweight, as shown in **Figure 8**. While stress analysis shows that the three welds would be adequate to secure the counterweight to the flexplate and even meet the requirements of SFI 29.1, the fewer number of welds increases the probability of a counterweight separation in the event of a defective weld.

SFI 29.1 Update

In August of 2016, SFI changed its protocol for testing flexplates that are equipped with counterweights. According to the new rules: “For a model to be certified with counterweights, it must be successfully tested with counterweights in place. The flexplate must be balanced by additional weights by the manufacturer before submitting the part for testing.” With these changes, SFI has acknowledged that the securement of the flexplate counterweight is an important safety consideration and should be tested. However, as previously discussed, the testing requires a manufacturer to test only a single representative product every two years. Therefore, even with the new SFI protocols, defects in the securement of the counterweight would need to be monitored by the manufacturer on an individual basis to prevent a similar incident from occurring.

Conclusion

The root cause of the flexplate counterweight detachment was due to a manufacturing defect and failure to properly secure the subject counterweight to the flexplate at the time of assembly. The lack of weld penetration over a small effective weld perimeter allowed the counterweight to fail after minimal use.

Resistance welds that were a part of the original design for securement of the counterweight to the flexplate

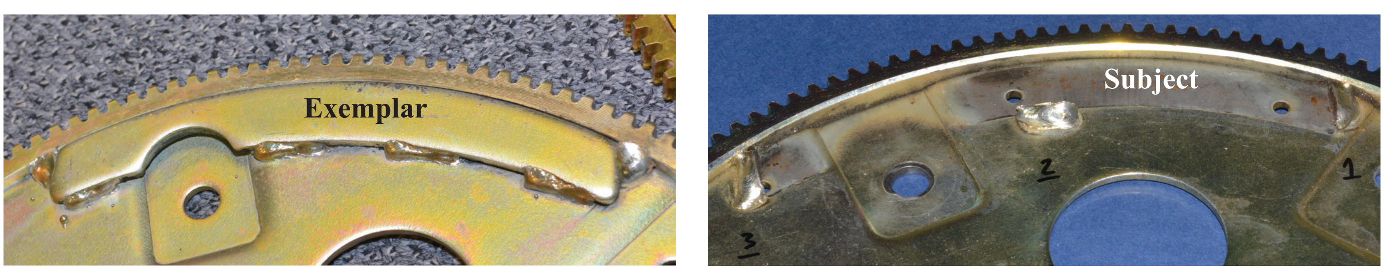

Figure 8
Comparison of the counterweight securement between an exemplar and the subject flywheel.

were omitted by the manufacturer on the subject product. Because the counterweight became detached and struck a crew member involved in the racing event, the manufacturing defect is also the cause of the subject incident. Due to the manufacturing process, which involves coating the flexplate after assembly, certain welding defects would not be visible to those handling the product after it was manufactured.

The manufacturer of the flexplate did not have an active quality control plan in place, and the defective weld went unnoticed until the subject accident. While the reseller of the flexplate completed and passed the SFI 29.1 certification process on a representative flexplates sample, it did not have involvement in the quality of each unit. In fact, SFI 29.1 certification is a destructive process, preventing the tested product from being put into service after testing. None of the companies related to the sale/resale of the subject flexplate had a role in quality control regarding the securement of the counterweight other than the original manufacturer of the part. However, because the reseller certified and placed its brand name on the product as if it was the manufacturer, it was held accountable for quality control even though these measures were outside of its control.

References

1. National Hot Rod Association (NHRA), Glendora, CA.

2. Specialty Equipment Market Association (SEMA), Diamond Bar, CA.

3. SFI Specification 29.1-2006. Quality Assurance Specifications: Automatic Transmission Flexplates. Diamond Bar, CA; SFI Foundation Inc.

4. Ibid.

5. Ibid.

6. SAE J1456-1984r1995. Maximum Allowable Rotational Speed for Internal Combustion Engine Flywheels. Warrendale, PA; Society of Automotive Engineers.

7. SAE J1240-1991. Flywheel Spin Test Procedure. Warrendale, PA; Society of Automotive Engineers.