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Maintaining the Accuracy of Charpy Impact Machine*

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Abstract: The quality of the data developed by impact machines tends to degrade over time, due to the effects of wear and vibration that are inherent in the test. This is the reason that impact standards specify periodic direct and indirect verification tests. Each year, we provide reference specimens for indirect verification of over 800 machines around the world. From evaluation of the absorbed energies and the fractured specimens, we are able to deduce the origin of energies that are outside the allowed ranges, and report these observations back to the machine owners. This report summarizes the basis for these observations and will allow, it is hoped, machines to be maintained at higher levels of accuracy.

Keywords: absorbed energy, Charpy V-notch, impact test, machine repair, misalignment, verification testing, worn anvils

Introduction

The low cost and simple configuration of the Charpy impact test have made it a common requirement in codes for critical structures such as pressure vessels and bridges. However, accurate results can be obtained only from impact machines that remain in good working condition, such as within the tolerances specified by ASTM Standard Test Methods for Notched Bar Impact Testing of Metallic Materials (E 23). We find that many of the critical tolerances can be monitored by post-fracture examination of the standardized verification specimens that we distribute.

Our examination of over 2000 sets of these specimens each year allows us to identify problems that are often not recognized during routine measurement of machine dimensions or routine check procedures. We have learned to recognize what marks on the broken verification specimens indicate factors that could be affecting the results. We can then

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advise our customers to recheck or replace the anvils or the striker, tighten bolts, check bearings, check machine alignment or level, check cooling bath or thermometer, or review testing procedures. This paper describes the most common problems that we detect, and gives advice on how to avoid or correct most of them.

Direct Evaluation

A routine check consists of a free swing check and a friction and windage check. The free swing is a quick and simple test to determine if the dial or readout is performing accurately. A proper zero reading after one swing from the latched position is required on a machine that is equipped with a compensated dial. Some machines are equipped with a non-compensated dial. Such a dial is one on which the indicator cannot be adjusted to read zero after one free swing. The user should understand the procedure for dealing with a non-compensated dial. This information should be available from the manufacturer.

The friction and windage test will give the user the condition of the bearings. We suggest that any deviation of more than 5% is excessive and the bearings should be inspected.

We suggest that the user develop a daily log or shift log to be kept with the machine. The log can be used to track the zero and friction values. The log can also include information such as number of tests, materials tested, and any other useful comments. A sample log is attached as Appendix 1.

Machine Preparation

The Charpy test is a dynamic test. Therefore, bolts may loosen over time. The tightness should be checked on the anvil bolts, the striker bolts, and the baseplate bolts. The manufacturer can supply the torque values for the anvil and striker bolts. The base-plate bolts should be torqued to the recommended torque values for the grade and size of the nuts and bolts. We recommend the use of “J” or “T” bolts only. (See Appendix 2.) We do not recommend lag type bolts. These bolts are made to withstand only static loads. We believe that over time, the insert portion of lag bolts will loosen in the concrete. As lag bolts are continually tightened, they can pull out of the concrete and be tightened against the base of the machine, giving the impression of a properly mounted machine. This condition is very difficult to detect. A machine with this problem will cause high energy values at the low-energy level. The procedure used to mount the master reference machines is attached as Appendix 2.

The anvil and striker radii should be carefully inspected for proper dimensions and for damage. Damage can be detected easily with a visual inspection and a check for smoothness by running a finger over the radii. We find that radius gages are usually inadequate to measure the critical radii. We recommend making molds of the radii and measuring the molds on an optical comparator. Occasionally even a new set of anvils and striker may have incorrect radii. We recommend that new anvils and strikers be inspected before being installed in the machine. Since the radii can be considered consistent before use, they can be measured directly on an optical comparator or other optical measurement system.

We recommend centering tongs such as those described in ASTM Standard E 23. The tongs should be inspected for wear or damage. A proper set of tongs is critical for the accurate placement of the specimen. Some machines are equipped with a centering device. The device should be inspected for wear and proper operation. We do not recommend the use of centering devices for low temperature testing because it can delay the time between removal from the bath and fracture, and so may exceed the allowed five-second interval.

The temperature indicator should be calibrated immediately before testing. Since ice water and dry ice have constant temperatures, they make quick and easy calibration media.

Post-Fracture Examination

Many machine problems can be monitored by post-fracture examination of the NIST standardized verification specimens. Following are the most common of these problems. In many cases, suggestions on how to correct or avoid them in the future are included.

Worn Anvils - Most of the wear of an impact test machine occurs on the anvils and striker. We evaluate this wear by examining the gouge marks that are formed on the sides of high-energy specimens when they are forced through the anvils. Anvils that are within the required tolerance of the standard will make a thin, even gouge mark all the way across both pieces of the broken specimen. As the anvils wear, they will make a wider, smeared mark across the specimen halves. Figure 1 shows the change in the gouge marks. When the wider smeared marks are observed on a customer's specimens, we recommend that the anvils be changed, because the reduction in energy needed to push the specimens through worn anvils eventually drops the machine below the lower tolerance in the energy range. You can monitor the wear on your machine by retaining some specimens that are tested with new anvils and comparing them to specimens of

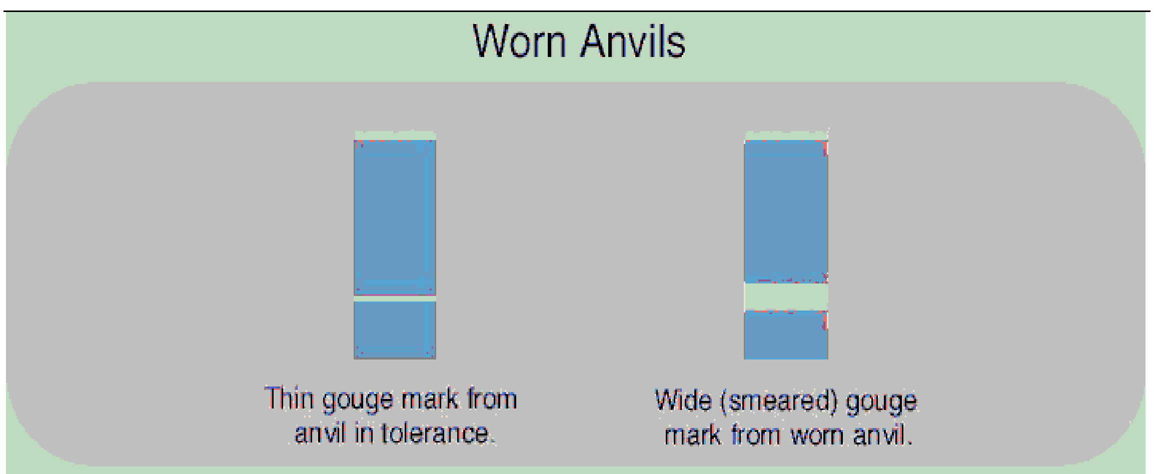

Figure 1

similar composition and hardness that are tested as the anvils wear. For specimens at a similar absorbed energy, the gouge marks will grow wider and smoother as the anvils wear.

Off-Center Specimen - An off-center specimen strike occurs when a specimen is not centered against the anvils, so the striker contacts the specimen to the side of the notch. The low-energy specimen best indicates when an off-center strike occurs. We identify this condition on the specimens by finding that the gouge marks caused by the anvils are not equidistant from the machined notch edges, and the striker gouge mark is offset the same amount from the notch (Figure 2). Also, as seen in Figure 2, the fracture surface of a correctly tested low energy specimen is flat and both halves are even. However, the fracture surfaces of a specimen that has been tested off-center are on an angle. The more off-center the strike, the steeper the angle will be. This problem increases the energy needed to fracture a specimen. The most common causes for this slipping are worn or damaged centering tongs, a worn or misaligned machine centering device, careless test procedures, or the use of a cooling fluid that is too viscous at the test temperature, which causes the specimen to float on the specimen supports. Most machine manufacturers should be able to provide new centering tongs. We have found that ethyl alcohol is one of the best cooling media because it seems to evaporate quickly from the bottom of the specimen to prevent specimen floating.

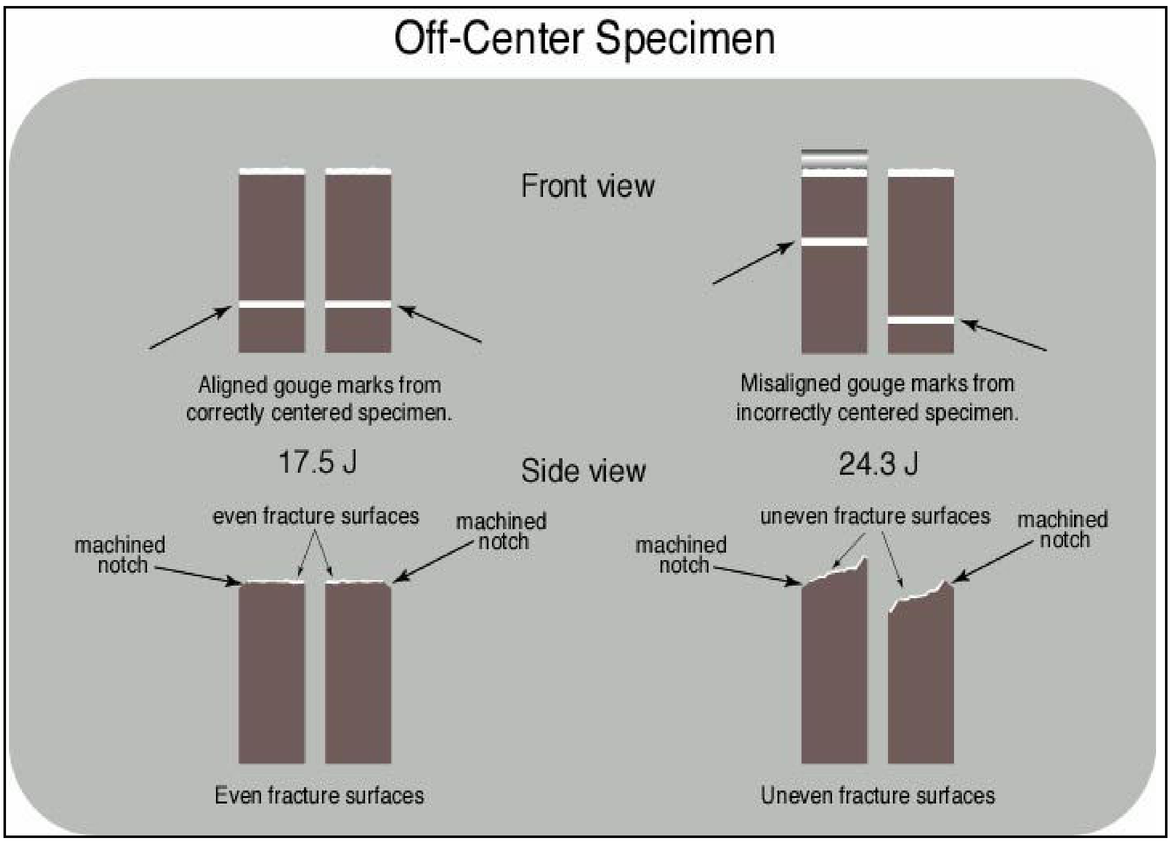

Figure2

Off -Center Striker - This differs from the off-center specimen in that the specimen is centered against the anvils so the anvil gouge marks are equidistant from the machined notch edges. However, the striker does not contact the specimen precisely opposite the notch. Figure 3 shows this appearance. An off-center striker is usually attributed to the pendulum shaft shifting off center. This shift can be the result of a loose alignment ring on the shaft or a loose bearing block on the machine. This problem also increases the energy needed to fracture specimens at all energy levels.

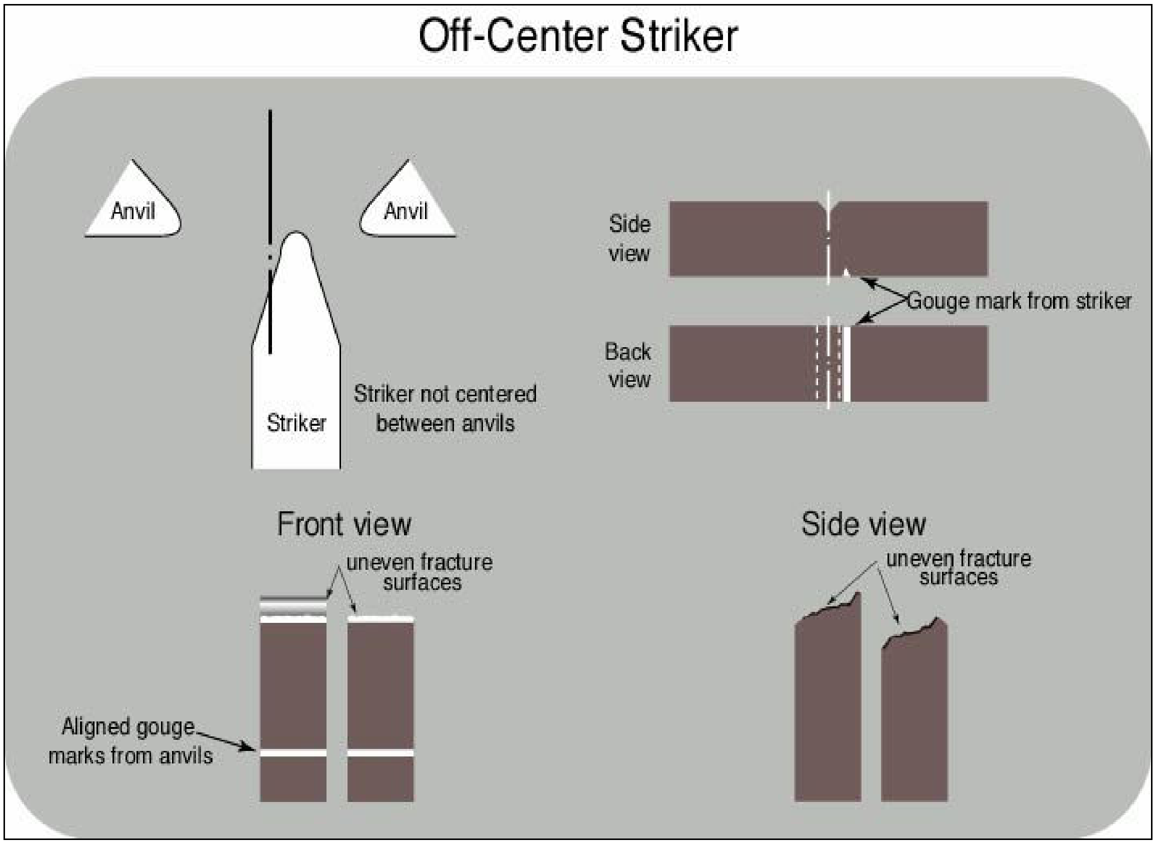

Figure3

Uneven Anvil Marks - Frequent testing of subsize specimens can cause the anvils to wear unevenly. Figure 4 shows an example of these uneven wear marks at each energy level of our reference specimens. Since this wear is restricted to a small area that the full-size reference specimen contacts, there is usually no effect on the energy required to fracture the specimen. This anvil condition presents two problems. First, since subsize wear is usually not indicated by a change in the energy required to break a reference specimen, inspection of the broken specimen is required. This wear will cause the anvils to be out of tolerance according to the requirements in the standard. This means that the machine does not meet the direct verification requirements of the standard and is therefore not eligible for the indirect verification process. The second, and more important problem, is that the subsize specimens are being tested in an area of the anvil that is worn. When the wear is substantial, this condition will produce artificially low sub-size energy values. The anvils should be replaced on a machine with this condition.

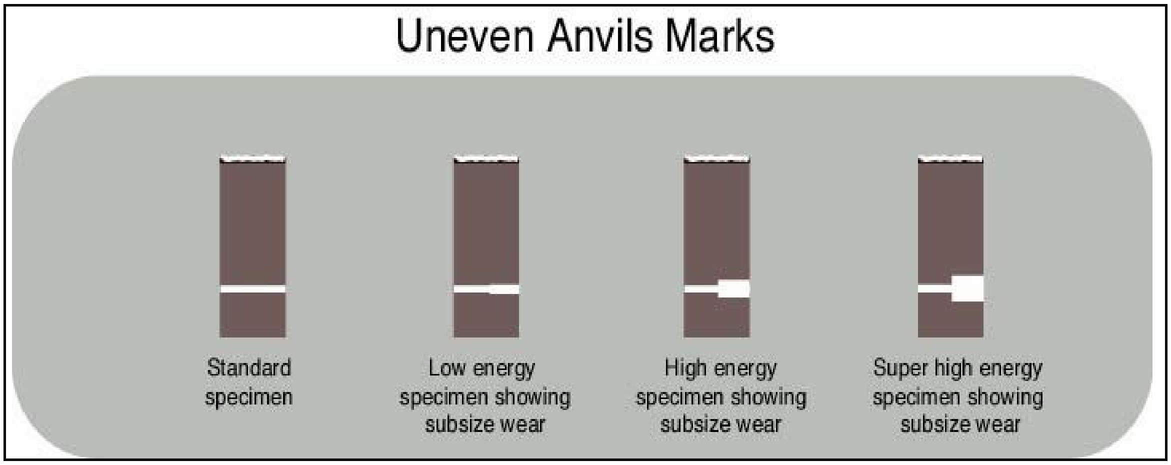

Figure 4

Chipped Anvils - Sometimes an anvil can be chipped. Figure 5 shows that this condition can be detected easily on all three energy reference specimens. The low-energy specimen is affected the least amount because it is the hardest specimen and therefore has a more brittle fracture. The ductile high-energy specimen will produce higher than normal energy results and the very ductile super-high-energy specimens are affected most by a chipped anvil. This condition should be detected easily by a visual inspection before using the machine. New anvils are required when an anvil is chipped.

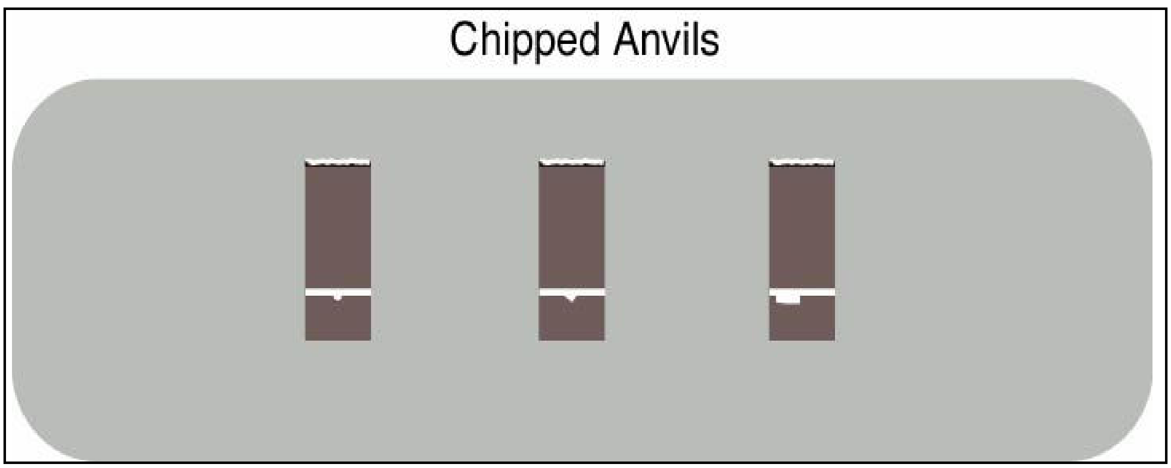

Figure 5

Anvil Relief - Some Charpy machine manufacturers have designed a machined relief at the bottom of the anvil (Figure 6). This anvil design does not meet the direct verification requirements of ASTM Standard E 23. The relief has caused high-energy results in our ductile high and super-high-energy specimens. It can also cause twisting of the specimens, during fracture, that may also contribute to energy values higher than normal at all energy levels. Since the relief is designed into the anvils and does not appear to add an excessive amount of energy to the test, we at NIST continue to verify these machines.

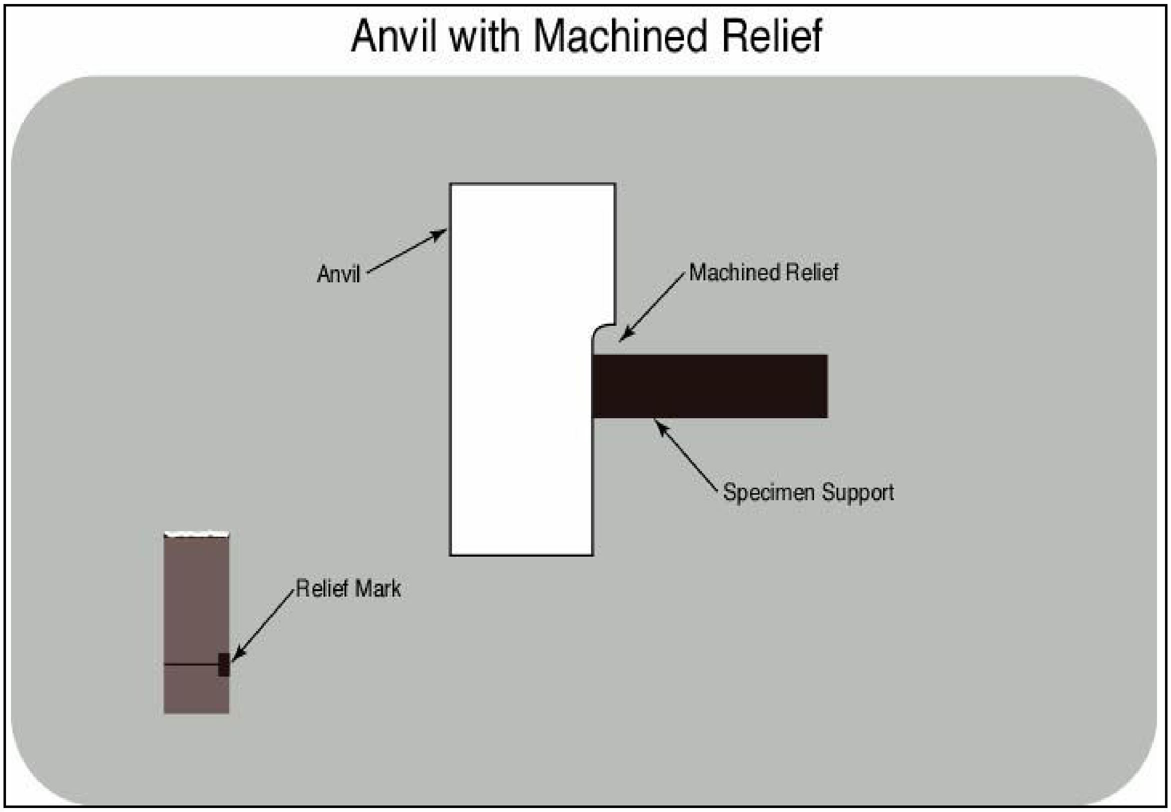

Figure 6

Damaged Anvils - Under some test conditions, usually for elevated temperature testing, the anvils can wear to a rough finish that creates excessive friction (Figure 7). This damaged condition is detected best on the high and super-high specimens. Damaged anvils usually cause the gouge marks to become wider and push the specimen material to form a ridge that can easily be detected with the fingernail. This damage usually causes artificially high energy results at the high and super-high energy levels. Damaged anvils must be replaced.

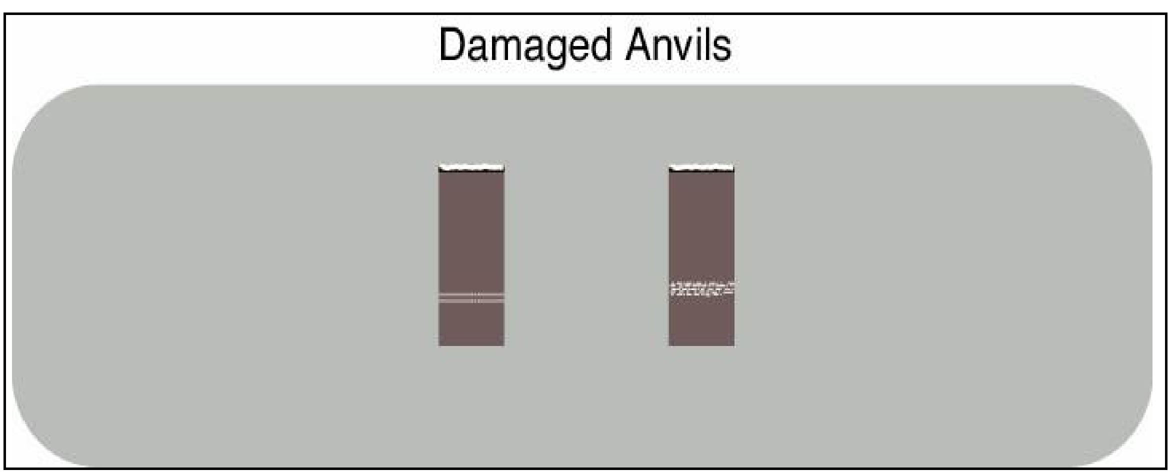

Figure 7

Bent Pendulum - Figure 8 shows the gouge marks created by a pendulum bent in the direction of the swing. This gouge mark is usually deeper on the top edge of the specimen as it sits in the machine. As shown in Figure 9, the striker contacts the top edge of the specimen first, causing excessive tumbling and twisting. This excessive activity can cause the specimen to interact with the striker or the pendulum after fracture to create additional energy loss. A bent pendulum can be detected by placing an unbroken reference specimen in the machine and placing a piece of carbon paper on the surface opposite the notch. At this point, lightly tap the striker against the specimen. This will make a mark on the specimen that can be inspected. If the pendulum is not bent, the mark should appear the same width across the specimen. If the pendulum is bent, the mark will be wider at one edge and become thinner or even not visible at the other edge (Figure 8). We recommend that a new pendulum be installed on a machine with this problem.

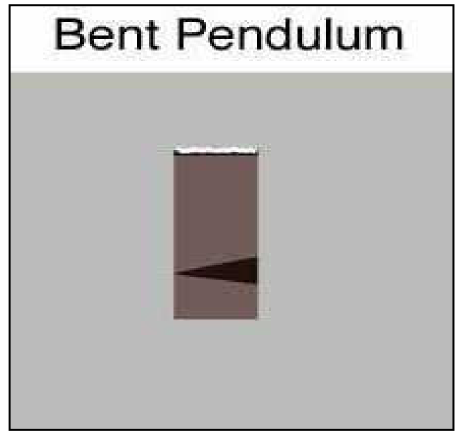

Figure 8

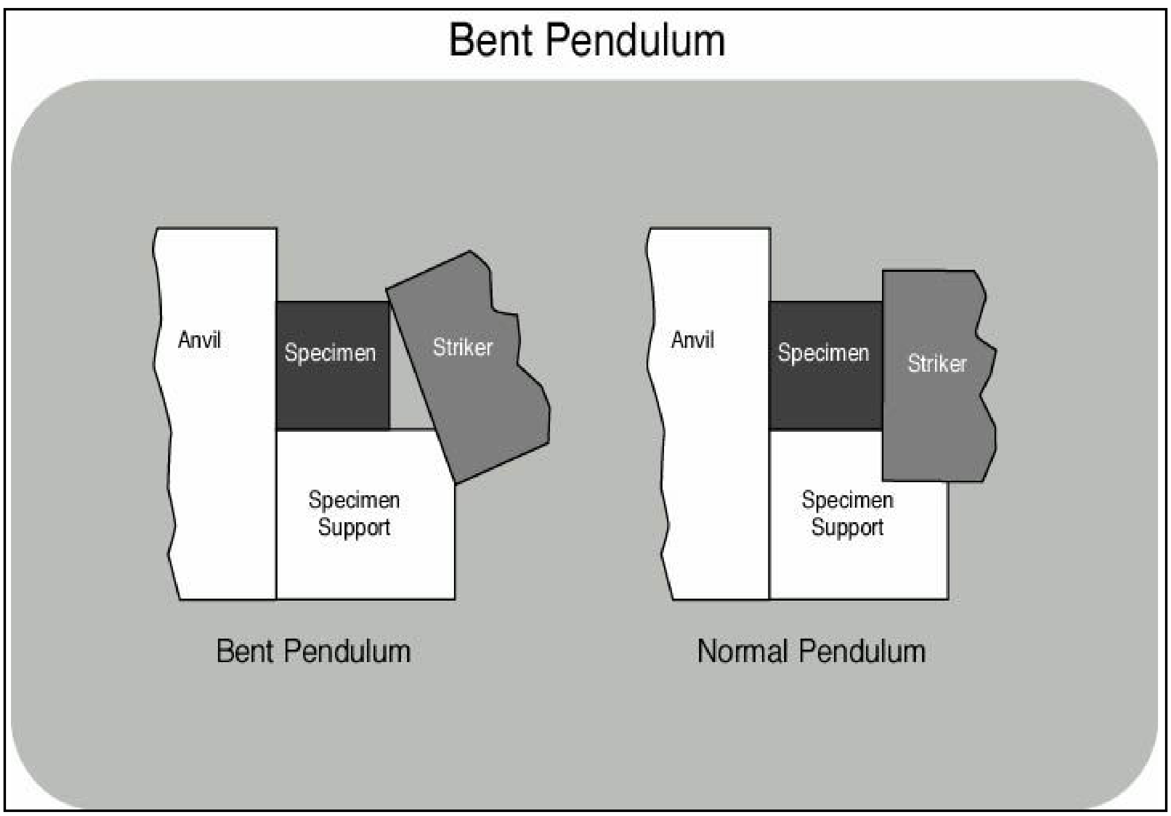

Figure 9

Summary

The condition and accuracy of Charpy machines cannot be checked only by comparing results of NIST reference specimens to the Master Reference Machines located at NIST, Boulder, CO. Some machine problems cause artificially low results while other machine problems cause artificially high results. In addition, deviations in procedures can cause similar results. These machine problems and procedural deviations may go undetected for years without some sort of physical check. For this reason, examination of the broken specimens is a critical part of the verification process. Many machine problems can be avoided or corrected with the information presented in this paper. Also, suggested changes in procedure can help can help to insure a successful test. To obtain verification specimens or to clarify procedures for verification testing, you may use the following information:

Verification specimens can be ordered from the NIST Standard Reference Materials Program. Phone: (303) 497-6776 Fax: (303) 948-3730 email: SRMINFO@nist.gov

Questions on verification procedures can be answered by the Charpy Program Coordinator. Phone: (303) 497-3351, fax: (303) 497-5939, or email: daniel.vigliotti@nist.gov

APPENDIX 1

EXAMPLE LOG

DATE	FREE SWING VALUE		FRICTION VALUE		COMMENTS
	DIGITAL (J)	DIAL (ft-lbf)	DIGITAL (J)	DIAL (ft-lbf)	

APPENDIX 2

MOUNTING PROCEDURE FOR REFERENCE CVN MACHINES

This is a detailed procedure developed by NIST to mount the three Master Charpy Reference Machines. This procedure is not intended to be substituted for any installation procedure provided by the manufacturer of the machine.

The foundation of the impact machine is critical to insure accurate results. Energy losses through the foundation must be kept to a minimum. We recommend making a foundation of 7000 pound mix concrete that measures 152.4 cm (60 in.) long by 91.4 cm (36 in.) wide by 45.7 cm (18in.) thick. Usually you will need to cut a hole in the floor to accommodate the new foundation. If other equipment in the area could affect the machine operation, you should isolate it from the floor with expansion-joint material.

Hold-down bolts used to secure the machine to the foundation should be of the inverted "T" or "J" type. The bolts, nuts, and washers should have a strength of grade 8 or higher. We recommend using bolts with a diameter of 22 mm (7/8 in.). At NIST we used 22 mm (7/8 in.) grade 8 threaded rod, cut into pieces 61 cm (24 in.) long. We then welded 22 mm (7/8 in.) pieces of the same threaded rod, six inches long, to the end of the 61 cm (24 in.) pieces to make inverted T bolts.

We then positioned the machine over the center of the foundation hole. The machine was held approximately 10.2 cm (4 in.) above the floor using spacers suitable to hold the weight of the machine. The T bolts were positioned in the machine-base mounting holes with a nut below and above the base of the machine. The nuts were tightened to keep the T bolts straight while the concrete was poured. The ends of the T bolts were positioned approximately 2.5 cm (1 in.) from the bottom of the hole. The machine was then leveled on the spacers. Leveling did not need to be as accurate as the final leveling. Reinforcement bars were attached to the top of the horizontal rod previously welded to the bottom of the T bolts. The reinforcement bars were attached in the form of a box connecting the four bolts. Another box formation of reinforcement rods was attached to the T bolts 25 cm (10 in.) above these rods. The concrete was then poured under the machine. The concrete was finished as level as possible at this time. Before the concrete fully hardened, we removed concrete from around each T bolt to create a cavity of approximately 2.5 cm (1 in.). This cavity would enable a nut to be threaded below the surface of the concrete. The machine was left in this position for 72 hours.

After 72 hours, the nuts on top of the base plate were removed and the machine was lifted off the T bolts. The bottom nuts were then threaded down into the cavities created before the concrete hardened. The nuts were left high enough on the T bolts to enable the use of an open-end wrench to adjust them after the machine was positioned on them. At this point, the base of the machine was coated with a light oil to keep grout from adhering to it. The machine was then lifted onto the T bolts and was positioned on the adjustment nuts. The machine was now ready to level. A machinist's level was used to insure meeting the tolerance of 3:1000 in. The critical leveling procedure was done using the four nuts under the machine. After the machine was leveled, we wrapped the outside of the nuts with duct-seal putty to facilitate their removal from the T bars later in the process.

At this point, the base of the machine was ready to grout. Heavy cardboard forms were placed around the base of the machine to keep the grout under the machine. It was necessary for the grout to flow completely under the machine, making sure the base of the machine was in total contact with the grout. The grout was installed under the machine. The machine was left in this position for 72 hours.

After 72 hours, the machine was lifted off the T bolts. The grout was inspected for cavities and for surface contact with the bottom of the machine. The putty was removed form around the nuts. The nuts were removed from the T bolts. After removing all debris from the grout, the machine was lifted over the T bolts and rested on the grout. Washers and nuts were installed and tightened. The level was checked at this point. The T bolts were cut off to approximately 12.7 mm (1/2 in.) above the nuts. The nuts were torqued to 380 ft-lb. The final level was checked at this point.

NOTE:
Special non-shrinking grout is recommended. This grout is available at most industrial hardware stores.

If you have any questions concerning this procedure, please contact Daniel Vigliotti by phone at (303) 497-3351, by fax at (303) 497-5939, by email at daniel.vigliotti@nist.gov, or by mail at NIST, Division 853, 325 Broadway, Boulder, CO 80303-3328.