Strength Characteristics of Swine Injection Devices

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Summary and Implications

Various needle gauges, lengths, and hub material was tested under static loading conditions. Significant differences exist in the needle industry in terms of strength and failure rate. Needle breakage was found to occur only when a bent needle was straightened and then reused. Manufacturing differences were found especially in the bond that joins the needle/hub assembly resulting in significant differences in failure rate.

Introduction

Needles that break during the injection phase or broken needles ingested by pigs have the potential for entering the food chain. Packers routinely sieze needles that at some point in the pig's life were either ingested or left embedded in the tissue from an injection event. This research project was started to provide a basic understanding of needle/hub strength characteristics and to identify the situations that might contribute to needle breakage.

Materials and Methods

Several hundred needle/hub assemblies were obtained from two manufacturers (brand A, brand B). Two lengths (1.0, 1.5 in.), three needle gauges (20, 18, 16), and two hub-types (aluminum [AL], polypropylene [PL]) were obtained. Not all combinations were possible. Table 1 outlines the needle/hub combinations that were tested.

Tests Conducted
The following tests were conducted:

1. *Needle/hub compression test*: Tests were conducted on stainless steel (SS) needles with either an aluminum (AL) or polypropylene (PL) hub. An MTS Syntec (Model 60/D) test stand was used with a special mounting assembly to conduct each test. The testing set-up is shown in figure 1.

2. *Needle/hub lateral bending test*: Each possible needle/hub combination was tested for lateral bending strength as shown in figure 2.

3. *Needle/hub full-embedment test*: Needle/hub assemblies were tested for lateral bending strength at the base of each needle/hub joint as shown in figure 2. This test was conducted to test the breakage strength assuming the needle was fully embedded in the animal and the animal subsequently moves laterally.

4. *Needle/hub reload after bending*: Needle/hub assemblies were retested for lateral bending strength after a permanent deformation resulted from the original lateral bending test. This test was conducted to determine the needle breakage tendency after straightening an already bent needle.

5. *Hide puncture strength*: Tests were conducted on fresh pig cadavers to test the puncture strength of pig tissue at various regions of the body. An apparatus was built using a calibrated spring to measure hide puncture strength. Needle gauges of 20, 18, and 16 were used.

Testing procedure

Separate containers were labelled for each of the possible needle/hub assemblies tested. All assemblies were then placed in each container and mixed. When a loading test was conducted, the appropriate containers were gathered and placed near the testing apparatus. Equally sized cards were made indicating each treatment combination for testing and these were placed in a separate container. When testing began, a card was randomly selected and this treatment combination was tested. The card was placed back into the container and the process was repeated until each treatment combination was tested. Five replications were conducted for every test. A test was conducted to verify that five replications was sufficient to draw statistically similar results compared to 10, 15, and 20 replications. An ANOVA was conducted to determine the significance of each treatment tested.

Results and Discussion

The results and discussion are included below. Results have been categorized by manufacturer, with the final section summarizing a comparison test between manufacturers.

Brand A needle/hub testing

Table 2 summarizes basic strength results for the Brand A needles tested. Testing results are summarized for compression, lateral bending, and full-embedment testing.

Compression test results indicate clear differences between AL and PL hub needles within any gauge/length combination tested, with AL hub needles exhibiting clear superiority over PL hub needles. Within any gauge needle tested, the 1.0 in. needle was clearly superior in compression strength versus a 1.5 in. needle. As needle diameter increased (decreasing gauge), within similar lengths, compression strength increased accordingly. For 1.0 in. AL hub needles, increasing the needle size from 20, 18, and 16 gauge increased the compression strength to failure from 35.6, 110.8, and 182.5 lb., respectively. For compression testing, all treatments and their interaction were statistically significant (P<0.01).

Similar trends were observed for the lateral bending test (tip bending; table 2). Absolute strengths to failure for lateral bending were far less than those measured for compression strength. This is very important because all needle/hub assemblies will experience lateral bending whenever the needle begins tissue embedment and a pig subsequently moves laterally relative to the needle injection angle. For lateral bending, all treatments and their interaction were statistically significant (P<0.01).

The embedment bending test results (table 2) show the strength of needle/hub assemblies assuming that the needle has been fully embedded within the pig, and then the pig moves laterally relative to the needle injection angle, with the needle held fixed. As shown in table 2, strength to failure increased dramatically as needle diameter increased, but remained nearly constant within a given needle diameter for a 1.0 versus a 1.5 in. needle. This finding was expected because under this loading the tip position of the needle is not experiencing the load and thus should not affect strength to failure results. For the full embedment results, the 18 gauge needle behaved differently for AL versus PL hub needles. For example, the 1.0 in. 18 gauge AL assembly had a strength to failure of about 24.9 lb. With the same needle attached to a PL hub, the strength to failure dropped to about 10.9 lb. Clearly, with this scenario, an AL hub assembly provided superior strength characteristics. For full-embedment testing, only needle gauge was found to be statistically significant (P<0.01).

Brand B needle/hub testing

Brand B delivered a full range of PL hub needles but not AL hub needles and thus the results are summarized for PL hub needles only, as shown in table 3.

Compression and lateral bending strength results follow similar trends as described for the brand A needles. Strength increases as needle diameter increases and needle length decreases. These effects were statistically significant (P<0.01). The full embedment test results show very little change in strength regardless of the gauge or length tested; a contrast to the brand A PL hub assemblies. Statistically, only needle gauge was significant (P<0.01).

Comparison between manufacturers

For all comparable PL needle assemblies between brand A and brand B, brand A assemblies had a higher strength to failure level versus brand B assemblies with the exception of the 1.0 in. 20 gauge needle under compression where the trends were not as clear. When loaded in compression or laterally at the tip, the gauge, length, manufacturer, and gauge x manufacturer interaction were significant (P<0.01).

Types of failure found

Four basic types of failure were found with the needle/hub assemblies studied. Three of these failures are shown in figure 3: outlining needle failure, needle/hub joint failure, and hub failure. The fourth type of failure was needle breakage, and this will be discussed in detail later. Table 4 summarizes the type of failure and occurrances of each type for the needle/hub assemblies studied (ND=needle deformation, BF=bond failure, HD=hub deformation, HF=hub failure).

One noticeable result was the bond failure rate comparison between manufacturers during compression testing. For the PL hub needles, brand B needles had a 46.7% failure rate (14/30) whereas brand A needles had a 20% failure rate (4/20). Clearly, manufacturing differences were found with this needle/hub/loading situation.

Puncture strength of pig hide

An apparatus was developed to test and compare the puncture strength of pig hide at various locations of the pig (figure 4). These results are shown in table 5. Puncture strength increased as needle diameter increased for every location studied. The lowest puncture force required was 0.15 lb for the neck region with a 20 gauge needle. The highest puncture force required was found at the back region using a 16 gauge needle (6.35 lb). Within consistent gauge needles, the back region required the highest puncture force, and the neck region required the lowest. Gauge, location, and their interaction were all significant (P<0.01).

Needle breakage

Clear differences in strength based on needle gauge, length, hub material, and manufacturer exist in the needle industry. These differences were shown using standard strength of material testing procedures under controlled laboratory conditions.

This project started because of the abundance of broken needles that have been found in processed pork. Surprisingly, for **all** tests conducted, not a single needle broke during testing. This result was not expected.

It was theorized that in some cases bent needles were being reused after straightening. This scenario was tested to prove or disprove the hypothesis. The procedure was to test AL hub needles after needle deformation occurred from the full-embedment test (figure 2). Under this loading scheme, needle deformation was concentrated at the base of the needle. With this condition, restraightening the needle and reloading caused decreased load to failure results and subsequent needle breakage. Table 6 summarizes the results from this testing procedure. The results are summarized for AL hub brand A needles.

As shown in table 6, load to failure decreased dramatically with each reload of a deformed needle. For example, the 18 gauge 1.5 in. needle failed at an average 28.7 lb as supplied by the manufacturer. If the needle was straightened and reloaded again, the average load to failure decreased to 18.4 lb. If the needle was straightened again and reloaded a third time, the average load to failure decreased to 5.0 lb. For the 90 needles tested in this manner, 87 broke after or during the third loading, resulting in a 96.7% failure rate. The results shown in table 6 confirmed our hypothesis of needle failure when reloading an already bent needle.

Needle bending versus hub deformation

If needles are not allowed to bend at a concentrated point, then it is conceivable that they could be reused, provided that their sharpness remains intact. Ideally though, needles should not be used if they need to be straightened first.

One noticeable feature between AL and PL hub needles was the distribution of load between the needle and hub under lateral and full-embedment load testing. If an AL hub needle was used, then most of a lateral load was transferred to the needle resulting in a much higher occurrance of needle bending. Conversely, for PL hub needles most of a lateral load was transferred to the weaker PL hub resulting in a permanently deformed PL hub, unsuitable for reuse.

The observation was made that an ideal needle/hub assembly would be one that allowed the needle to sway slightly with a lateral or full-embedment load without affecting the hub/needle joint. With this scenario, the needle would not permanently deform and thus could be reused without the need for straightening, and thus possibly breaking on reuse.

Differences in needle/hub strength characteristics exist in the industry. Clear differences exist between AL and PL hub needles, with AL hub needles exhibiting superior overall strength characteristics. Needle length is an important factor as well, except for cases where lateral loading is administered on a fully-embedded needle. The shorter the needle the larger the load that can be sustained. Needle gauge is a very important factor, with 16 gauge needles far superior in strength to 18 and 20 gauge needles.

The problem of needle breakage appears to be one of needle misuse. These results show that needles and hubs were resilient to breakage with not a single needle breaking if used and loaded a single time. If however, a bent needle is straightened and reused, the risk of needle breakage is quite high. Needles should not be reused if the needle experiences a permanent deformation. Clearly, reusing a permanently deformed needle results in a much lower load to failure strength and a high risk of breakage.

Tests are currently being conducted where pig movement is being added as a treatment condition. A pig movement simulator has been built to accomodate this test. This device allows for lateral pig movement and adjustments to needle injection angle. Results from this test currently are being gathered but were not completed at the time of this writing. A simulated hide reflecting the puncture strength of pig hide has been installed and can be easily changed for various hide puncture strength levels.

Preliminary results indicate a large occurrance of PL hub failures. Upon impact with the pig movement simulator, PL hubs are violently fractured leaving the needle and a portion of the hub embedded in the hide. Future results and work with this test apparatus will help quantify any defects in needle/hub assemblies when pig movement is added to the complexity of this problem.

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Table 1. Needle/hub combinations tested.

Gauge	Length (in.)	Hub Material	Manufacturer Brand A	Manufacturer Brand B
20	1.0	AL	x	
20	1.0	PL	x	x
20	1.5	AL	x	
20	1.5	PL	x	x
18	1.0	AL	x	
18	1.0	PL	x	x
18	1.5	AL	x	
18	1.5	PL	x	x
16	1.0	AL	x	
16	1.0	PL		x
16	1.5	AL	x	
16	1.5	PL		x

Table 2. Brand A needle/hub loading results (lbs). Results shown for SS needles and either aluminum (AL) or plastic (PL) hubs. All loadings represent the average of 5 replications.

Gauge	Length (in)	Compression		Tip bending		Embedment bending	
		AL	**PL**	**AL**	**PL**	**AL**	**PL**
20	1.0	35.6	29.4	1.2	1.2	9.2	9.2
20	1.5	22.7	21.4	0.6	0.6	9.6	8.8
18	1.0	110.8	65.2	3.6	2.8	24.9	10.9
18	1.5	63.6	46.8	2.0	1.72	8.7	10.7
16	1.0	182.5	*	7.4	*	42.7	*
16	1.5	129.4	*	4.2	*	40.6	*

* 16 ga plastic hub needles not available from Brand A

Table 3. Brand B needle/hub loading results (lb). Results shown for SS needles and plastic (PL) hubs. All loadings represent the average of 5 replications.

Gauge	Length (in)	Compression	Tip bending	Embedment bending
20	1.0	32.1	1.0	6.7
20	1.5	17.4	0.4	6.4
18	1.0	45.8	1.8	6.4
18	1.5	34.8	1.0	6.0
16	1.0	64.4	2.9	9.0
16	1.5	57.7	1.6	8.7

Table 4. Frequency of failures observed.

Supplier	Hub	Loading Arrangement **Tip Bending**	**Compression**	**Embedment**
Brand A	AL	30-ND	28-ND 2-BF	30-ND
Brand A	PL	20-HD	16-ND 4-BF	18-HD 2-HF
Brand B	PL	30-ND	15-ND 14-BF 1-HF	30-ND

Table 5. Puncture strength of pig hide (lb) as a function of needle gauge and puncture location. Strength represents the average of five readings on a single 200 lb pig.

Gauge	Front Shoulder	Hip	Neck	Rear	Back
20	0.20	0.84	0.15	0.79	1.84
18	0.62	3.04	0.35	1.72	4.81
16	2.51	3.53	1.06	1.76	6.35

Table 6. Reload straightened needles from a prior needle failure. Results shown used the apparatus shown in figure 3. Assemblies were allowed to fail initially, then straightened and reloaded twice. Results refer to the AL hub brand A needles.

Gauge	Length	Loading **First**	**Second**	**Third**
20	1.0	9.2	6.5	4.6
20	1.5	9.6	9.2	5.0
18	1.0	24.9	17.4	10.2
18	1.5	28.7	18.4	5.0
16	1.0	42.7	24.2	*
16	1.5	40.6	21.4	*

* broke after second loading.

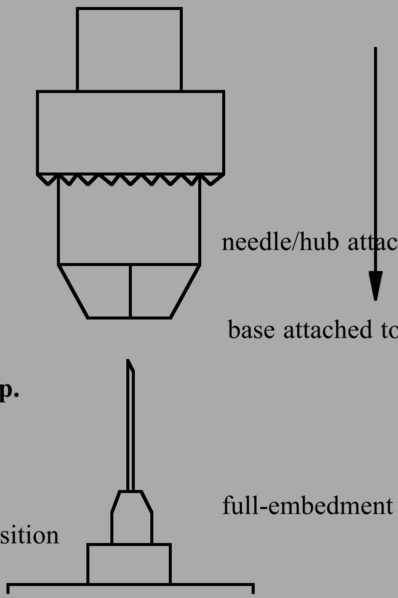


Figure 1. Compression test set-up.

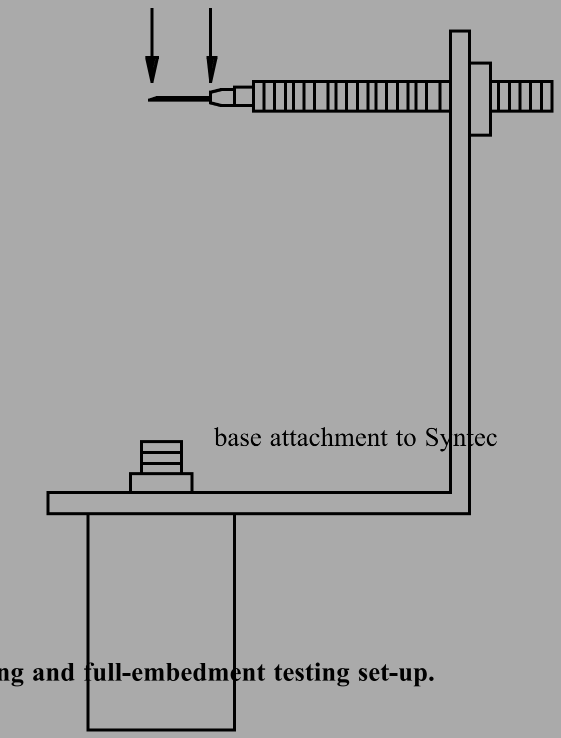
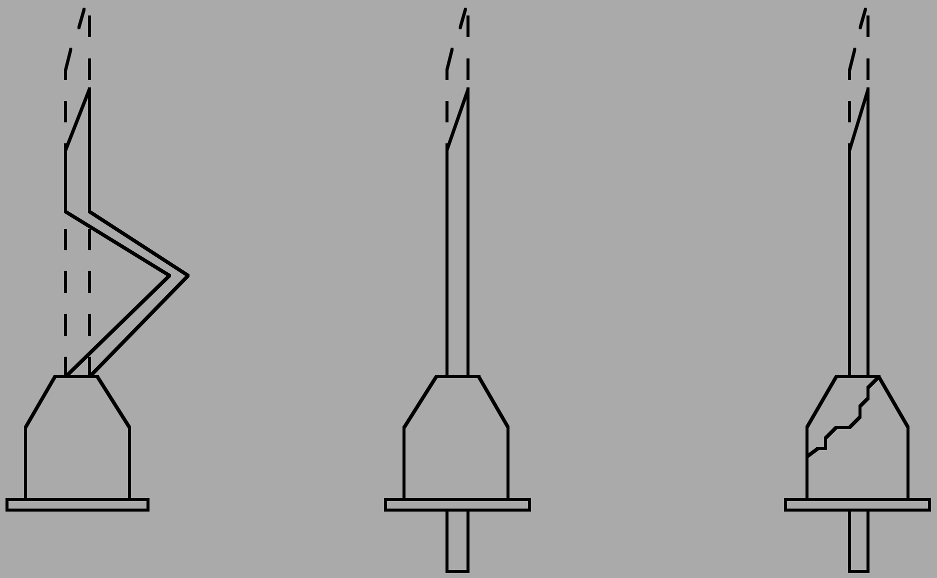


Figure 2. Lateral load tip-bending and full-embedment testing set-up.



needle failure bond failure hub failure

Figure 3. Various failures witnessed during compression testing.

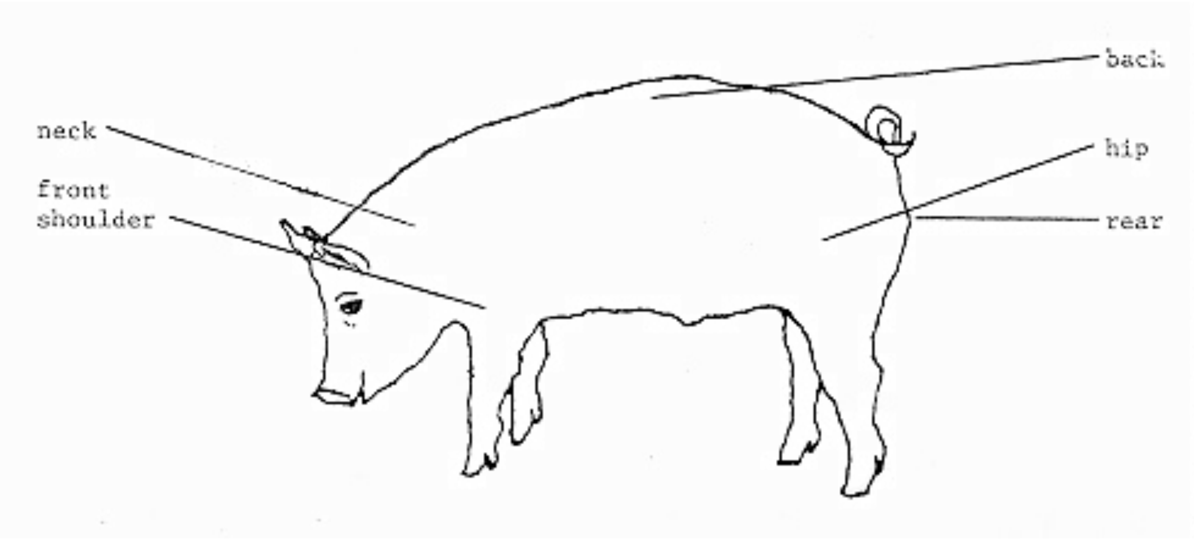


Figure 4. Site locations where hide puncture strength results were conducted.