Holz als Roh- und Werkstoff 56 (1998) 253–258 © Springer-Verlag 1998

Holding strength of T-nuts in solid wood and wood composites

C. A. Eckelman

T-nuts, Figure 1, are widely used in furniture construction, particularly in those applications where the nut must be anchored to the furniture structure or where the nut will be inaccessible once the furniture is covered, e.g., with upholstery. Despite their widespread use, information is lacking concerning both the static and dynamic holding strength of T-nuts. Since such information is essential for the rational product engineering of furniture, a brief study was undertaken to obtain preliminary estimates of the static holding strengths of representative types of T-nuts in a variety of woods and wood composites. In general, the study was limited in scope and was intended to provide empirical estimates of T-nut holding strength rather than definitive design factors. Results are given in the report which follows.

Festigkeit von Gewindemuttern in Massivholz und Holzwerkstoffen

T-Gewindemuttern sind weit verbreitet in Möbelbau, vor allem bei Anwendungen, bei denen die Muttern in der Möbelkonstruktion verankert werden oder wo sie nach der Fertigung unzugänglich sind oder bedeckt werden z.B. durch Polster. Trotz ihrer weiten Verbreitung fehlen Informationen über statisches und dynamisches Haltevermögen. Solche Informationen sind eine wesentliche Voraussetzung für einen rationellen Möbelbau. Daher wurde diese Untersuchung durchgeführt, um vorläufige Schätzwerte der statischen und dynamischen Festigkeit verschiedener repräsentativer Typen von Gewindemuttern in Holz und Holzwerkstoffen zu gewinnen. Die Arbeit beschränkt sich darauf, empirische Werte zu erhalten und zielt nicht auf endgültige Konstruktionsfaktoren ab.

1 Overview of the study

In general, the study could be divided into three parts. In the first part, the holding strengths of a single size of T-nut in a variety of substrates were determined in order to obtain information about the relative holding strengths of various woods and wood composites. In the second part, the holding strengths of a variety of sizes of a single type of T-nut in a single high-strength substrate were determined in order to obtain estimates of the maximum holding strengths of the nuts as a function of size. Finally, in the third part, the holding strengths of a variety of sizes and types of T-nuts in a single substrate were determined in order to obtain first estimates of the variations in strength that must be anticipated when nuts are casually selected from a representative portion of the global T-nut population.

Carl E. Eckelman
Purdue University, Wood Research Laboratory,
1200 Forest Products Building, West Lafayette,
IN 47907-1200, USA

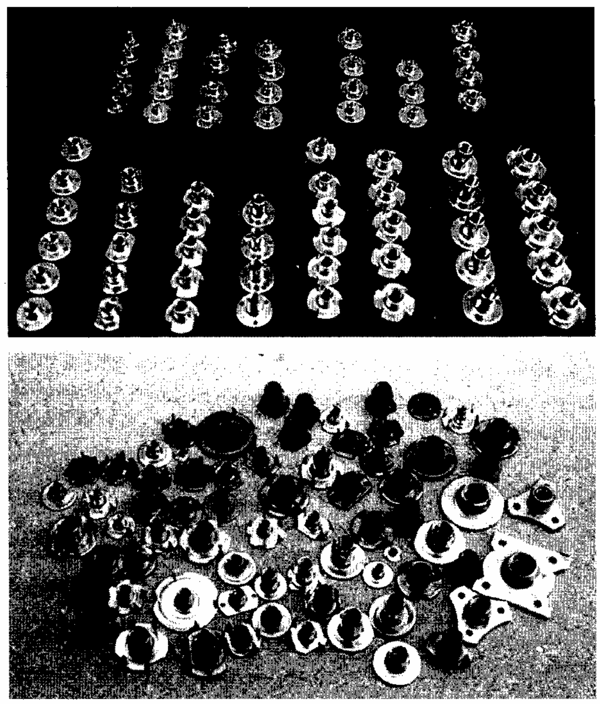


Fig. 1. Photograph showing several types of T-nuts included in the study
Bild 1. Abbildung verschiedener hier untersuchter T-Gewindemuttern

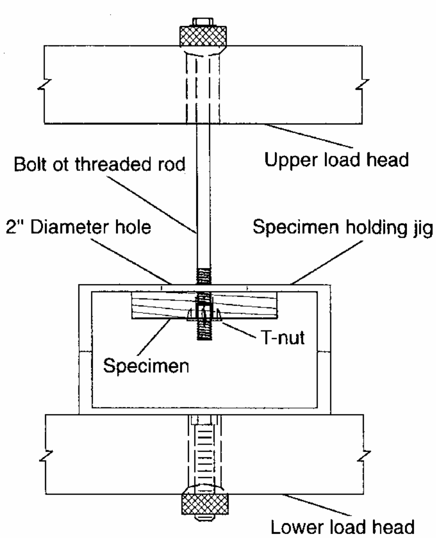


Fig. 2. Diagram of apparatus used to load T-nuts from the "top"
Bild 2. Schema der Prüfapparatur für die Festigkeit von T-Gewindemuttern bei Belastung „von oben"

2
Description of test specimens

The size of the specimens used in the study was not strictly controlled, but most specimens measured from 2-1/2 (64 mm) to 4 inches (100 mm) wide by about 6 inches (150 mm) long. Thickness varied from 3/4 inches (19 mm) to 1-1/4 inches (32 mm). All of the material was conditioned to an average of 6 percent moisture content. Once conditioned, a hole was drilled through the center of the specimen to receive the T-nut. Diameter of the "pilot" hole was equal to the diameter of the shaft of the T-nut it was to receive. A clamping device was used to press the T-nut into the wood or composite.

The 1/4-inch (6.4-mm) T-nuts used in the first part of the study were of a single type and were obtained from a single source. The T-nuts used in the second part of the study were of several types but were obtained from the same source as those used in the first part of the study. Sizes included 6–32 (0.138 in., 3.5 mm), 8–32 (0.164 in., 4.2 mm), 10–24 (0.190 in., 4.8 mm) and 1/4 (6.4), 5/16 (7.9 mm), 3/8-inch (9.5-mm) nuts. The T-nuts used in the third part of the study were of several types which were obtained from several domestic and international sources. Sizes included 4–40, 6–32 (0.138 in., 3.5 mm), 8–32 (0.164 in., 4.2 mm), 10–24 (0.190 in., 4.8 mm), and 1/4 (6.4), 5/16 (7.9 mm), and 3/8-inch (9.5-mm) nuts.

3
Description of method of test

All tests were carried out on a Riehle universal testing machine. Two methods of test were used. An exploratory test indicated that the two methods yielded identical results.

In the first method of test (Fig. 2) the nuts were loaded in much the same manner they are used in service. The apparatus used in this method of test consists of a specimen holding fixture which is attached to the lower cross-head of the testing machine and a length of high strength threaded rod, one end of which is attached to the upper cross head. The fixture which held the specimens was constructed of two 8-inch (200-mm) lengths of steel channel welded together to form a box section 8 inches long (Eckelman 1978; Eckelman and Cassens 1984). A 2-inch diameter hole was drilled through the center of the top plate of the fixture. Similarly, a 3/4-inch hole was drilled through the bottom of the fixture exactly in line with the longitudinal axis of the first hole. A 3/4-inch diameter bolt passed vertically downward through the second hole and was anchored by means of rounded nut to the ball seat of the bottom crosshead. A length of threaded rod, anchored to the ball seat of the top crosshead, was then inserted into the face of the specimen and screwed into the T-nut. Before a specimen was loaded, the rod was centered in the 2-inch opening in the support plate so that loads were applied free of eccentricity. The specimen was supported completely around the insert by the plate. This type of fixture helps to prevent splitting along the grain owing to bending forces generated during the test. A problem arises when the nuts are loaded in this manner, however, in that rod failures rather than nut failures may occur with standard strength rods. This is a problem with some 1/4-inch and with all smaller fasteners. By loading the nuts as described below for the second method, this problem is totally eliminated.

In the second method, the specimens were supported on their bottom side by a structure whose principal component was a metal plate with a 2-inch (50.8-mm) diameter hole drilled through its center, (Fig. 3). This fixture was constructed of an 8-inch (200-mm) length of steel channel with a 2-inch (50.8-mm) diameter hole drilled through the center of the web surface.

In practice, a specimen was placed on top of the support fixture and centered over the hole with the flange face of the T-nut exposed on the top surface. A flat headed ma-

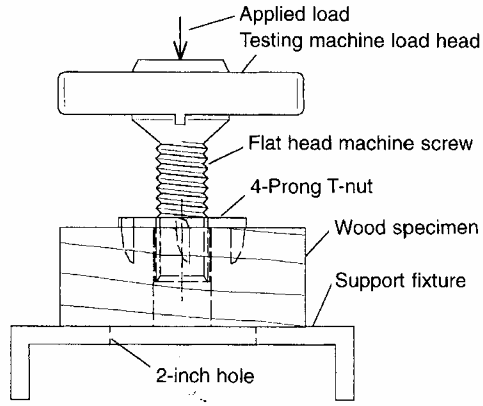


Fig. 3. Diagram of apparatus used to load T-nuts from the "bottom"
Bild 3. Schema der Prüfapparatur für die Festigkeit von T-Gewindemuttern bei Belastung „von unten"

Table 1. Holding strengths of 1/4-inch (6.4 mm) T-nuts with 4-prong heads in various woods and composites. A 5/16-inch (8 mm) diameter pilot hole was used for all specimens
Tabelle 1. Festigkeit von T-Gewindemuttern mit 4 Zacken in Verschiedenen Hölzern und Werkstoffen. In allen Proben war ein 8-mm-Loch vorgebohrt

No. of Spec	Wood Species or Composite	Load Lbs.	Std. Dev. Lbs
3	Ash, white	2083	41
3	Basswood	1608	74
3	Birch, yellow	1870	95
3	Butternut	943	80
3	Cedar, incense	930	26
3	Cedar, W. Red	820	20
3	Cherry, black	1953	101
3	Douglas fir	1727	47
3	Elm, American	1637	26
3	Fir spp.	1185	18
3	Hickory spp.	2113	85
3	Lauan spp.	1510	78
3	Locust, black	2080	0
3	Mahogany spp.	1957	46
3	Maple, red	1330	17
3	Maple, sugar	1897	49
13	Oak, red	1990	78
3	Oak, white	2063	76
3	Pine, South. spp.	1240	37
3	Redwood	1820	191
3	Sassafras	1673	107
3	Spruce spp.	873	40
3	Walnut, black	1873	126
8	Yellow-poplar	1754	141
3	PBd-1	1127	55
3	PBd-2	1167	52
3	PBd-3	1210	44
3	PBd-4	1350	34
3	Softwood Plywood	1378	65
3	MDF-1	1388	28
3	MDF-2	1637	45
3	MDF-3	1670	52
6	Hardwood Plywood	1850	96

Table 2. Description and holding strengths of single source T-nuts
Tabelle 2. Spezifikation und Festigkeit verschiedener Gewindemuttern von einem Hersteller

ID	No. of Spec.	Bolt Diam	Pilot Hole Diam.	Head Type	Stem Length in.	Stem Type	Ult. Load Lbs.	Std. Dev. Lbs
a	5	6–32	5/32	3-tooth	0.25	Straight	666	31
b	5	8–32	3/16	3-tooth	0.25	Straight	1216	65
c	5	10–24	15/64	Round	0.3	Straight	1678	127
d	2	10–24	15/64	3-tooth	0.3	Straight-1	1715	115
e	4	10–24	15/64	3-tooth	0.3	Straight	1718	43
f	3	10–24	1/4	3-tooth	0.3	Straight-2	2253	5
g	5	1/4	19/64	Flat	0.3	Straight	1738	95
h	5	1/4	19/64	Round	0.56	Straight	1974	119
l	5	1/4	19/64	3-tooth	0.25	Straight	2056	283
j	5	1/4	19/64	3-tooth	0.3	Straight	2114	203
k	5	1/4	19/64	Round	0.3	Straight	2302	113
l	5	1/4	19/64	3-tooth	0.5	Straight	2671	138
m	5	5/16	23/64	Round	0.38	Straight	2195	123
n	5	5/16	23/64	Round	0.56	Straight	3002	328
o	5	3/8	29/64	3-tooth	0.38	Straight	3738	145

1-Thin wall; 2-thick wall

chine screw was then screwed into the insert from the flange-face side of the nut until all the threads of the nut were engaged. A load was then applied to the flat face of the machine screw by means of the load head of the testing machine. Loads were applied until a T-nut either failed or was pressed through the substrate. Rate of loading was 0.05 inches (1.3 mm) per minute.

4 Results and discussion

Results of the tests are presented in Tables 1–3. Mean values are presented for clarity in bar graphs, Figs. 4–6.

Part I

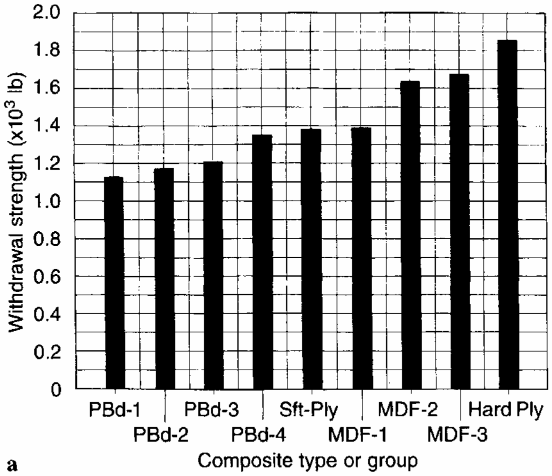
All of the results presented in Table 1 and Figs. 4a–c were carried out with 1/4-inch (6.4-mm) T-nuts; hence the results provide a comparison of the holding strengths of the various materials shown. In general, two types of failure occurred. Either the nuts themselves failed, or, the wood below the nuts crushed allowing the nuts to be pulled deeply into the substrate. Results for specimens in which the wood crushed are shown in Fig. 4b, whereas results for specimens in which the nut fractured are shown in Fig. 4c.

The range of values obtained with the materials tested (for the specific T-nut used) varied from a little less than 1200 pounds for particleboard to 2000 pounds and slightly above for the denser hardwoods. The T-nuts failed cleanly at the root in the denser woods such as red oak, (Fig. 4c). In woods with somewhat lower crushing strengths, the flanges of the T-nuts tend to bend upward before the nut fractures. In the case of the woods with significantly lower

Table 3. Holding strengths of T-nuts obtained from a variety of sources
Tabelle 3. Spezifikation und Festigkeit von Gewindemuttern von verschiedenen Herstellen

X X ID	No. of Sp	Bolt Diam.	Pilot Hole Diam.	Head Type	Stem Length in.	Stem Type	Ult. Load Lbs.	Std. Dev. Lbs
a	2	4–40	1/8	3-tooth	0.125	Straight	383	8
b	2	6–32	11/64	3-tooth	0.25	Straight	713	38
c	5	8–32	13/64	Flat	0.18	Straight	1573	8
d	5	10–24	15/64	4-tooth	0.38	Tapered	1344	77
e	3	10–24	15/64	4-tooth	0.25	Straight	1663	45
f	4	10–24	15/64	3-tooth[1]	0.3	Straight	1781	73
g	4	10–24	15/64	Round	0.3	Threaded	2123	369
h	1	10–24	15/64	Round	0.38	Straight	2010	0
i	1	10–24	15/64	Flat	0.25	Straight	1260	0
j	8	1/4	5/16	6-tooth[2]	0.25	Straight	2024	241
k	4	1/4	5/16	4-tooth	0.38	Tapered	2319	88
l	2	1/4	5/16	Round	0.3	Threaded	2500	70
m	2	1/4	5/16	Round	0.5	Threaded	2280	5
n	1	1/4	5/16	Flat	0.25	Straight	1825	0
o	2	5/16	3/8	Round	0.7	Straight	2840	100
p	2	5/16	3/8	Round	0.56	Threaded	3475	95
q	3	5/16	3/8	Round	0.56	Straight	3857	300
r	8	5/16	3/8	3-tsqh	0.38	Threaded	2194	391
s	2	5/16	3/8	4-tooth	0.38	Straight	3020	200
t	1	5/16	3/8	4-tooth	0.56	Straight	3940	0
u	1	5/16	3/8	Flat	0.38	Straight	2400	0
v	1	5/16	15/32	Triang	0.38	Straight	1600	0
w	3	3/8	29/64	4-tooth	0.44	Straight	3000	574
x	1	3/8	29/64	Round	0.44	Straight	2650	0
y	2	3/8	29/64	Round	0.44	Threaded	5060	120
z	2	3/8	29/64	Flat	0.44	Straight	2525	155

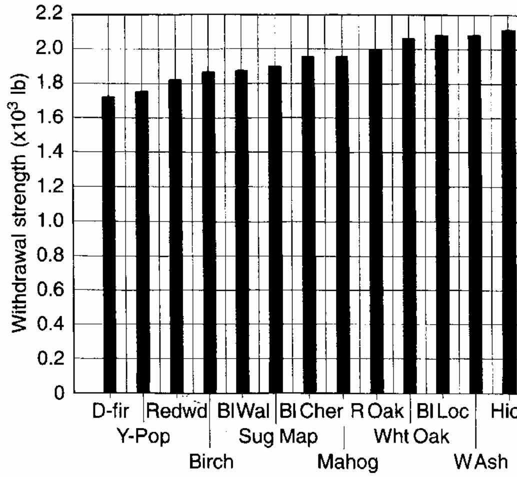
[1] Contains identical 3-, 4-, and 6-tooth nuts.
[2] Contains similar 4 and 6-tooth nuts.



a

Fig. 4a. Holding strength of 1/4-inch T-nuts in particleboard, medium density fiberboard, softwood plywood, and hardwood plywood. The keys for identification of the materials used are given in Table 4

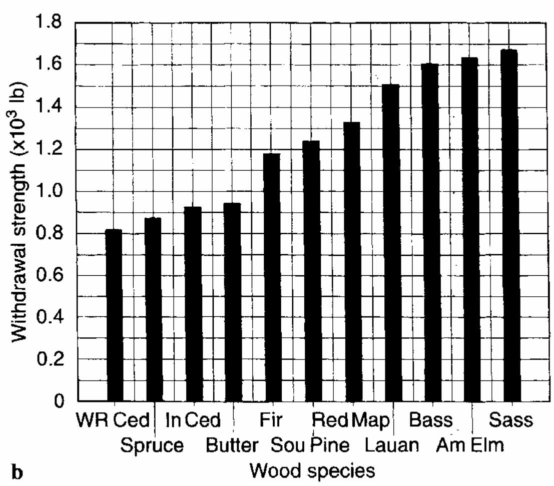
Bild 4a. Festigkeit von T-Gewindemuttern in Spanplatten, MDF sowie in Sperrholz aus Nadel- und Laubholz. Die Bezeichnungen der Proben sind in Tabelle 4 erklärt



c

Fig. 4c. Holding strength of 1/4-inch T-nuts in various "harder" woods. All of the failures shown occurred owing to fracture of the nut. The keys for identification of the woods are given in Table 4

Bild 4c. Festigkeit von T-Gewindemuttern in verschiedenen „härteren" Hölzern. Jedes Versagen war bedingt durch einen Bruch in der Mutter. Die Bezeichnungen der Proben sind in Tabelle 4 erklärt.



b

Fig. 4b. Holding strength of 1/4-inch T-nuts in various „softer" woods. All of the failures shown occurred because of crushing of the wood beneath the flange of the nut. The keys for identification of the woods are given in Table 4

Bild 4b. Festigkeit von T-Gewindemuttern in Verschiedenen „weicheren" Holzern. Jedes Versagen war bedingt durch Bruch des Holzes neben dem Flansch der Mutter. Die Bezeichnungen der Proben sind in Tabelle 4 erklärt

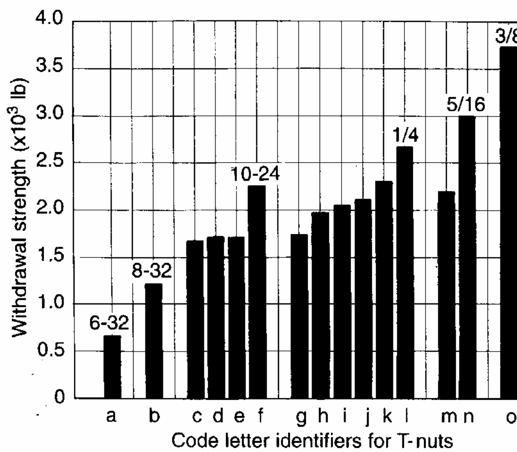


Fig. 5. Holding strength of various size T-nuts in red oak. All of the failures shown occurred owing to fracture of the nut. Results of the test provide an indication of the relationship of holding strength to fastener size. Keys for identification of the nuts are given in Table 2. English and metric equivalents for bolt sizes are given in Table 5

Bild 5. Festigkeit verschiedener Typen von T-Gewindemuttern in Eichenholz. Jedes Versagen war bedingt durch einen Bruch in der Mutter. Die Testergebnisse liefern auch Hinweise auf die Beziehung zwischen Festigkeit und Größe der Halterung. Abkürzungen sind in Tabelle 2 erklärt; englische und metrische Maße finden sich in Tabelle 5

crushing strengths, (Fig. 4b), the flanges of the T-nuts tend to bend and the nuts are pulled through the specimens. In the case of particleboard, on the other hand, the T-nut tends to „break through" the board. In essence, a circular „plug" of material is sheared from the board.

Part II

In the case of the T-nuts obtained from a single supplier and tested in red oak, there is a general increase in strength as the diameter of the fastener increases, Fig. 5. Ultimate holding strength of these fasteners would be expected to be directly related to the circumference of the fastener at the root of the shaft along with the thickness of the material. Thus, although strength tends to increase as diameter increases, strength is significantly affected by the thickness of the parent metal. As a result, increases in diameter may not produce expected increases in strength; furthermore, differences in material thickness may result in significant differences in strength within any single diameter class.

It is worthwhile to compare the strengths obtained with these fasteners to the strengths of the machine screws or bolts with which they are used. In tests carried out in this study, it was found that standard grade 3/8-inch (9.5-mm)

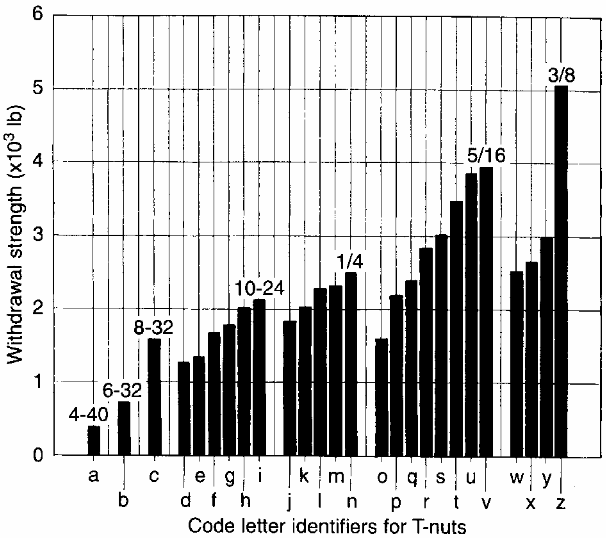


Fig. 6. Holding strength of several types and sizes of T-nuts obtained from several sources in red oak. Results of the tests provide an indication of the variations in strength that must be expected when fasteners are obtained without a priori knowledge of their holding strength. Keys for identification of the nuts are given in Table 2. English and metric equivalents for bolt sizes are given in Table 5

Bild 6. Festigkeit einiger Typen und Größen von T-Gewindemuttern verschiedener Hersteller in Eichenholz. Die Ergebnisse beinhalten auch Hinweise auf die zu erwartende Variation der Festigkeit, wenn Halterungen ohne Vorkenntnis ihrer Festigkeit verwendet werden. Abkürzungen sind in Tabelle 2 erklärt; englische und metrische Maße finden sich in Tabelle 5

diameter bolts failed under a load of about 6500 pounds, 1/4-inch (6.4-mm) diameter bolts failed under a load of about 2500 pounds, and 10–24 (0.190 in., 4.8 mm) bolts failed under a load of about 1200 pounds. Thus, it is important to note that for bolts with diameters of 1/4 inch (6.4 mm) and less, the T-nuts may develop more strength than the bolts used with them. As a result, connections made with bolts of these sizes should be designed on the basis of bolt strength rather than nut strength.

Part III

The results shown in Fig. 6 provide a further indication of the wide range of strengths which must expected with T-nuts of varying types, particularly when they are obtained from a variety of sources. As can be seen in the figure, some nuts are almost twice as strong as others in the same diameter class. These results clearly indicate that rational product design dictates the need for individual performance data for these fasteners.

5 Conclusions

Results of the tests indicate that high strength joints can be constructed with T-nuts, but that strengths tend to vary greatly depending on the style and the source of the nut. Hence, specific performance information is needed for each T-nut. Results also indicate that holding strength is strongly related to the mechanical properties of the substrate in which a T-nut is used. Highest results were obtained, therefore, with woods such as red oak, whereas lowest values were obtained with wood composites.

Table 4. Definition of woods and composites
Tabelle 4. Kennzeichnung der verwendeten Holzarten und Werkstoffe

Key	Commercial Name	Botanical Name
W Ash	Ash, white	Fraxinus americana
Bass	Basswood	Tilia americana
Birch	Birch, yellow	Betula alleghaniensis
Butter	Butternut	Juglans cinerea
In Ced	Cedar, incense	Libocedrus decurrens
WR Ced	Cedar, W. Red	Thuja plicata
BlCher	Cherry, black	Prunus serotina
D-fir	Douglas fir	Pseudotsuga menziessii
Am Elm	Elm, American	Ulmus americana
Fir	Fir sp.	Abies spp.
Hick	Hickory	Carya spp.
Lauan	Lauan .	Shorea spp.
Bl Loc	Locust, black	Robinia pseudoacacia
Mahog	Mahogany	Swietenia macrophylla
Red Map	Maple, red	Acer rubrum
Sug Map	Maple, sugar	Acer saccharum
Roak	Oak, red	Quercus rubra
Wht Oak	Oak, white	Quercus alba
Sou Pine	Pine, South	Pinus spp.
Redwd	Redwood	Sequoia sempervirens
Sass	Sassafras	Sassafras albidum
Spruce	Spruce	Picea spp.
BL Wal	Walnut, black	Juglans nigra
Y-Pop	Yellow-poplar	Liriodendron tulipifera
PBd-1	Particleboard	ANSI A208.1-1993-M-2
PBd-2	Particleboard	ANSI A208.1-1993-M-2
Pbd-3	Particleboard	ANSI A208.1-1993-M-2
PBd-4	Particleboard	ANSI A208.1-1993-M-2
Sft-Ply	Softwood Plywood	
MDF-1	Medium Density Fiberboard	ANSI A208.2-1994-MD
MDF-2	Medium Density Fiberboard	ANSI A208.2-1994-MD
MDF-3	Medium Density Fiberboard	ANSI A208.2-1994-MD
Hard Ply	HardwoodPlywood	

Table 5. Bolt size definitions and equivalents
Tabelle 5. Größe und Maße der Gewindemuttern

Size	Dia (inch)	meter (mm)	Threads per inch
4–40	0.112	2.8 mm	40
6–32	0.138	3.5 mm	32
8–32	0.164	4.2 mm	32
10–24	0.190	4.8 mm	24
1/4–20	0.250	6.4 mm	20
5/16–18	0.3125	7.9 mm	18
3/8–16	0.375	9.5 mm	16

Results of the tests clearly indicate that at least some types of T-nuts from some manufacturers are able to develop a high proportion of the strength of the machine screws or bolts used in conjunction with them. Holding strength differs greatly, from type to type and source to source, however. Hence, specific performance information is needed for each T-nut.

In high density woods such as oak, T-nuts fail owing to separation of the barrel from the flange. In the case of lower density woods, the T-nut may actually be pulled through the wood, or, pulled into the wood to the extent that the flanges are bent excessively.

Results also indicate that holding strength is closely related to fastener diameter, but it is also strongly affected by the thickness of the parent metal. Thus, T-nuts produced from say 16 gage material may be expected to be stronger than those produced from 18 gage.

Finally, 1/4-inch (6.4-mm) T-nut fasteners and smaller may develop more strength than the bolts used in conjunction with them. In designing a connection, therefore, it is important to determine whether the bolt or the nut limits the strength of the joint.

References

Eckelman CA (1978): Predicting withdrawal strength of sheet-metal type screws in selected hardwood. Forest Prod. J. 28(8): 25–28

Eckelman CA, Cassens DL (1984): Holding strength of metal inserts in wood. Forest Prod. J. 34(6):21–25