Slatted Floors and Solid Floors: Stress and Strain on the Bovine Hoof Capsule Analyzed in Finite Element Analysis

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ABSTRACT

An established finite element model of a bovine claw was used to compare mechanical stress levels in a loaded model claw on different types of flooring. The following situations were compared: a claw standing on a solid floor, a claw standing on the edge of a short tie stand, and claws standing on slatted floors with slats of 28 and 40 mm (wide) running parallel and perpendicular to the claw axis. Finite element analysis allowed visualization of stress peaks seen predominantly in the weight-bearing border of the dorsal abaxial wall and of the bulbar region and in the proximal axial wall. Maximum stress values of 13 MPa were found in the model claw loaded on the solid floor and values of 18 to 22 MPa were seen in the model claw loaded on the edge of the solid floor. On slatted floors, stresses increased in the situation in which the claw was not supported under the abaxial wall. Comparison between the other slatted floors showed little difference in amounts of mechanical stress. A clear distinction was detected between the solid floor with full claw contact and the slatted floors. From the point of view of the mechanical stress seen in finite element analysis, a large contact area between claw and floor, as seen in the solid surface floor, is preferable. When use of slatted floors is unavoidable, direction of the slats should run perpendicular to the direction of the walkway to prevent even more mechanical impact in certain footing situations.

Key words: cattle, flooring, pressure, claw lesion

INTRODUCTION

In a natural environment, the bovine claw interacts with more or less elastic ground surfaces that allow the claw to sink into the ground and facilitate load transmission. Flooring systems of various housing systems, however, must account for more complex demands than just loading conditions. Cleanliness of

flooring systems is an important factor in claw health affecting transmission of infectious diseases and slipperiness of flooring surfaces. Slippery floors lead to an increased step frequency (Phillips and Morris, 2001) and greater risk for leg injuries in cows (Webb and Nilsson, 1983). Cost, durability, and ergonomics are additional limiting factors.

Across Europe, various housing and flooring systems are in use. These include tie stalls with long or short stands, loose housing systems with or without free stalls, and combinations of these systems. Seasonal grazing on pasture and no grazing are observed; solid floors of concrete or asphalt, with incorporated aggregates to enhance grip (Phillips and Morris, 2001), and with different friction and abrasion coefficients (Telezhenko et al., 2004) are in use. Slatted floors are usually made of concrete elements at different slat distances, with the recent tendency of covering or replacing concrete slats with specially constructed, slatted rubber mats (Hultgren and Bergsten, 2001). Different bedding types (Webster, 2001; Laven and Livesey, 2004) or rubber mats in general (Bergsten, 2004), if used, show positive influences on the incidence of lameness (Cook, 2003), soundness of bovine claws (Lischer and Ossent, 2001; Manske et al., 2002), quality and microstructure of the hoof horn (Tarlton et al., 2002; Voges et al., 2004), and animal well-being (Fregonesi and Leaver, 2001; Bergsten, 2004). Major economic losses are caused by lameness and claw diseases (Blowey, 1998; Hultgren and Bergsten, 2001).

Choice of the flooring system used is primarily based on economical considerations and the optimization of the cleaning process. Braam and Swierstra (1999) tested coated and noncoated concrete samples of various surface roughnesses as a criterion for reducing urease activity. The aim was to reduce ammonia volatilization from bovine urine pools, but only cleaning strategies were found to efficiently reduce urease activity. Knowing the purely negative influence of excessive moisture, especially mingled with manure and slurry, on claw health and footing stability (Phillips and Morris, 2000; Telezhenko et al., 2004), further development of softer and cleaner housing surfaces should be encouraged. Unfortunately, all manure removal systems (e.g.,

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mechanical scrapers or hot water pressure) strain floor surfaces (Emmons, 1993), resulting in disintegration and change of surface properties like evenness, hardness, abrasion, and friction.

Interactions of claw and floor can be evaluated by bovine locomotion studies (Phillips and Morris, 2001) and bovine claw pressure- and force-plate findings (Scott, 1988; van der Tol et al., 2002; DeBelie and Rombout, 2003; Huth et al., 2004). Methods to determine stress and strain in the material of the claw include the use of strain gauges and the analysis of stress-imaging models in finite element analysis (FEA). These methods provide a unique way of looking at the real-time stresses and deformation of a model claw based on the geometric form and the actual characteristics of the material. The object in question is transformed into a finite element (FE) mesh model (see Figure 1b), which is attributed the material properties of the specific material from which different loading conditions and support situations can be calculated. Finite element analysis represents a modern technique for stress evaluation in materials testing and has already been established in veterinary research (Newlyn et al., 1998; Hinterhofer et al., 2001; McClinchey et al., 2002). Use of FE in materials analysis and the descriptive presentation of results make its application even more interesting for dairy science. Construction of the FE model claw and its stress analysis on soft and hard flooring is described in detail elsewhere (Hinterhofer et al., 2005b). No other comparable literature was found. The present study analyzed 7 specific situations of the FE model claw of a sound claw, loaded squarely on a model of a solid concrete floor, and on its edge, and loaded on 5 different slatted model floors. Results shown on the model claws with respect to pressure distribution, location of focal stress values, and maximum stress values in relation to the orientation, and type of support are evaluated and discussed for further improvement of bovine comfort.

MATERIALS AND METHODS

The FE Model Claw

One FE model claw was used for all calculations, introduced by Hinterhofer et al. (2005b; Figure 1a). Geometry of the model claw was based on the digitized image of a sound lateral hind claw of an Austrian Fleckvieh cow with claw measurements at the dorsal border of 78 mm, a heel depth of 38 mm, a heel length of 47 mm, and the diagonal from tip of the toe to the rear end of the hairline of 139 mm. The foot angle measured 50°. Before slaughter, the claw was trimmed to recognized functional claw trimming standards (Toussaint-Raven et al., 1985). After digitization using a 3-D scan-

ner (Westcam, Mils, Austria), finite element meshing (Figure 1b) was performed using IDEAS 10NX series (Structural Dynamics Research Corp., Electronic Data Systems Corp., Plano, TX). Finite elements of the model claw were attributed a modulus of elasticity of 600 MPa for the claw wall at the dorsal margin, dropping in 50-N increments to 200 MPa for the bulbar region and the sole (Hinterhofer et al., 2005a; Figure 1a). Claw material was attributed a Poisson's ratio of 0.3; all elements were defined as having linear elastic material properties.

Load was applied to the model claw via oriented force vectors, distributed evenly on the inside surfaces of FE of the claw wall according to the pattern of the suspensory apparatus with the vectors covering an area of approximately 3,500 mm². Load vectors deviated 5° plantar and 5° abaxial from the vertical. Total load used was 756 N, compared with the static load on 1 claw of a standing cow.

Different Floor Models

Two different FE model floors, a solid floor and a slatted floor, were simulated in 7 floor sets. The modulus of elasticity attributed to the finite elements of the floors was defined at 211,000 MPa as for plain steel (Beitz and Küttner, 1990). Each floor was assigned a Poisson's ratio of 0.3 and isotropic material properties.

Solid floor calculations (Figure 1a) simulated the model claw being loaded squarely on a solid floor (floor set 1) and loaded at the edge of a solid floor with the bulbar region not being supported (floor set 2) as it occurs during brief standing events and when entering or leaving a free stall. Slatted floor calculations were performed with slats 28 and 40 mm wide. Floor set 3 simulated the model claw being loaded parallel to a 28-mm slat with equal support for the axial and abaxial wall; floor set 4 simulated the claw loaded in the same position on a 40-mm slat. In floor set 5 the claw is placed perpendicular to the 40-mm slat; floor sets 6 and 7 present the model claw being supported only under the abaxial or the axial wall respectively (Figure 1). Contact-surface boundary conditions, regulating the contact situation between the model claw and model flooring types, were defined with frictional properties comparable to 0.6.

Calculations and Presentation of Results

Stress values were calculated as *von Mises* stress in megapascals, a comparative stress value that takes into account all occurring stresses in the 3 directions of the coordinate system and is determined by the standard equation $\varsigma = 1/\sqrt{2}\sqrt{(\varsigma_1 - \varsigma_2)^2 + (\varsigma_2 - \varsigma_3)^2 + (\varsigma_3 - \varsigma_1)^2}$

where ς stands for *von Mises* stress and ς_1 , ς_2 , ς_3 are the maximal principal stresses in the orientation of the 3 coordinates (Rumpel and Sondershausen, 1990). The IDEAS solution software gives results as result graphics (Figure 2) with or without the original mesh geometry of the selected model. Result graphics are equipped with a stress scale, expressed in a linear or logarithmic scale, with maximum and minimum stress or deformation values. Localization of stress values having greater differentiation to the surrounding stresses are best seen in the result graphics using a linear scale. General stress distribution in the material of the claw capsule is best analyzed in the result graphics using a logarithmic scale. Both color scales facilitate easier interpretation of the results. In addition, specific stress values of 25 selected locations around the weight-bearing border (WBB) and in 5 locations of the axial wall of each loaded model claw were compared.

RESULTS

The model claw in all floor sets showed stress distribution mainly along the WBB of the dorsal and dorsal abaxial walls and in the WBB of the heel, depending on the specific support situations. On the solear surface, little stress was detected in the center of the sole and in the center of the heel. The stresses calculated in the 7 floor sets on 30 positions of the model claw are provided in Table 1, with the location of the 30 positions shown in Figure 3.

In floor set 1, evaluated with a linear scale (solid floor, full support), the model claw calculated dense and high stress values (13.5 MPa; 100%) predominantly in the WBB of the dorsal wall and in the bulb area. Moderate stresses occurred in the proximal axial wall (5.8 MPa); comparably less stress (1.1 to 3.8 MPa) was evenly distributed along the WBB of the rest of the axial and abaxial wall. Using a logarithmic scale, the overall stress distribution of the claw capsule showed clear stress peaks in the dorsal and dorsal abaxial WBB. The bulb area calculated moderate but more evenly distributed stresses. Loading strained the proximal axial wall in a focal-stress zone close to the coronet and near to the dorsal margin.

In floor set 2 (solid floor, heel bulb, no support) using a linear scale, greatest stress values of up to 18 MPa (133%) occurred in the WBB of the abaxial and axial wall at the positions, where the support of the solid floor ended. Clear stress peaks were again calculated in the WBB of the dorsal wall (13 to 18 MPa); moderate stress occurred in the proximal axial wall (5 MPa). The rest of the WBB showed less stress between 0.7 and 1.4 MPa. The overall stress distribution in the logarithmic scale showed stress peaks in the dorsal and dorsal abax-

ial WBB. The edge of the solid floor imparted distinct stress peaks on both the axial and abaxial WBB at the area of contact, leading to a more widely distributed straining of the total axial wall.

When evaluated using the scale, the model claw in floor set 3 (slatted floor, 28-mm slats, axial and abaxial support) calculated the greatest stress values at the areas of contact in the WBB of the toe and in the bulb region (18 MPa; 133%). Moderate stress (4.5 MPa) occurred in the proximal axial wall; smaller to very small stress results were detected in the WBB of the axial and abaxial wall (0.2 to 2.8 MPa). In a logarithmic expression, focal stress areas developed in the axial and abaxial WBB at the edge of the contact area. Moderate straining occurred in the abaxial WBB and, similar to floor set 1, focal and proximally oriented stress zones strained the axial wall.

In floor set 4 (slatted floor, 40-mm slats, axial and abaxial support), expressed in a linear and logarithmic scale, the model claw showed the same distribution as in floor set 3, but with greater stress values. Supported areas of the WBB of the dorsal wall and heels calculated stress values up to 22 MPa (162%). Comparably low but still moderate stresses were detected in the proximal axial wall (5.8 MPa). Little stress occurred in the WBB of the axial and abaxial wall (0.9 to 2.3 MPa). Overall stress distribution of the claw capsule showed a very similar picture to that found in floor set 3, the focal stress zones at the axial and abaxial edge of the support being a little wider apart.

For floor set 5 (slatted floor, 40-mm slats, dorsal and plantar support) expressed using a linear scale, the model claw was turned 90° in relation to the slat direction. High stress values were found in the WBB of the dorsal wall and in the bulbar region (18 MPa; 133%); smaller stresses were calculated in the proximal axial wall (4.8 MPa). The rest of the WBB, where supported, showed small to moderate stress values (0.5 to 3.1 MPa). Stress distribution within the claw capsule was only minimally influenced by the perpendicular slat position. Stress results using a logarithmic scale were uniformly greater than in floor set 1, but distributed in the same manner.

In floor set 6 (abaxial support) evaluated using a linear scale, the model claw calculated very large stress values (20 MPa; 148%) predominantly in the WBB in the bulb area and large stresses in the WBB of the dorsal wall (13 MPa). Only mild stresses occurred in the proximal axial wall (3.4 MPa). Similarly low stress (1.1 to 3.8 MPa) was evenly distributed along the rest of the WBB of the abaxial wall (2.2 MPa), but 0.9 to 1.4 MPa were found in the unsupported WBB of the axial wall. Using a logarithmic evaluation, the FE model claw with only abaxial support showed maximum

Figure 1. All floors are equally hard with a modulus of elasticity of 211,000 MPa. 1a: Finite element (FE) model claw with full support platform, color shades indicate the modulus of elasticity from gray-light blue (200 MPa) to dark blue (600 MPa). 1b: FE mesh displayed of FE model claw and FE model floor. 2: Floor set 2 simulates a claw standing partially on the ground (e.g., at the end of a tie stall). 3: In floor set 3, an FE claw is loaded with a 28-mm slab being centered under the sole parallel to the axial wall. Floor sets 4 to 7 are calculated on a slatted floor with 40-mm slab width. 4: The FE model claw in floor set 4 is placed parallel to the slab. 5: In floor set 5, the slab is centered under the sole perpendicular to the axial wall. 6: In floor set 6, the axial wall is not supported. 7: In floor set 7, the abaxial wall is not supported.

Figure 2. Stress distribution within the finite element model claw of floor set 2 (above = no support under the heels) and floor set 6 (below = only abaxial wall supported); displayed in *von Mises* stress values in MPa with linear scale (blue) and logarithmic scale (yellow).

Table 1. Stresses seen in the 7 floor sets (MPa) on 30 positions of the proximal axial wall and along the weight-bearing border around the solear surface of the model claw. Positions 1 to 30 are indicated. Extruded stress values allow a selective, numerical comparison of desired positions of the model claw.

Floor set	Weight-bearing border																													
	Proximal axial wall						Axial wall						Heels						Lateral abaxial wall						Dorsal wall					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	2.5	5.8	5.8	0.4	2.5	0.3	2.5	1.6	1.1	1.1	1.6	1.6	2.5	3.8	2.5	0.7	3.8	13.5	0.4	0.7	1.1	1.6	1.6	1.6	2.5	2.5	2.5	5.8	13.5	13.5
2	2.6	5	2.6	5	5	1.4	9.6	2.6	1.4	1.4	1.4	1.4	1.8	18	0.1	0.3	0.3	0.3	0.7	0.7	18	18	0.3	0.7	0.7	1.4	5	9.6	1.4	18
3	1.1	4.5	0.4	1.1	1.1	1.1	1.8	1.8	1.1	1.1	0.6	0.4	0.2	2.8	1.1	1.1	0.6	18	7.2	1.1	1.8	1.8	1.8	1.8	1.8	1.8	7.2	4.5	2.8	29
4	2.3	5.7	5.7	2.3	3.6	5.7	1.5	2.3	2.3	2.3	2.3	1.5	0.9	1.5	22	0.9	0.6	0.3	22	0.9	1.5	1.5	1.5	1.5	1.5	1.5	14	2.3	2.3	22
5	3.1	4.8	1.3	3.1	4.8	0.5	0.5	1.3	0.8	1.3	1.3	1.3	1.3	2	2	3.1	4.8	18	0.5	1.3	2	2	2	2	2	2	3.1	7.4	18	7.8
6	1.5	3.4	0.3	1.4	2.2	0.9	0.9	1.4	1.4	1.4	0.9	0.9	0.9	1.4	3.4	5.3	3.4	20	0.9	2.2	2.2	2.2	2.2	2.2	2.2	8.2	13	13	2.2	2.2
7	5.9	9.4	2.3	5.9	1.5	9.4	24	3.7	3.7	2.5	2.5	1.5	1.5	61	3.7	38	2.3	0.1	0.5	0.5	0.9	1.5	2.3	2.3	2.3	2.3	2.3	61	38	15

¹Dorsal weight-bearing border (position 6).

stress peaks in the WBB of the abaxial wall at the location of the supporting edge. The rest of the abaxial WBB was highly strained without peaks. Although not supported, the axial wall calculated focal and proximally oriented stress zones up to 7.4 MPa.

Floor set 7 (axial support) calculated by far the greatest stress values of all floor sets, predominantly in the WBB of the dorsal wall (24 to 61 MPa) at the edge of the support and in the bulbar region (38 MPa; 281%). The proximal axial wall showed greatest stress results of up to 9.4 MPa. Stress in the WBB of the axial wall was moderate at 1.5 to 3.7 MPa and the rest of the claw capsule showed only small levels of stress.

DISCUSSION

Flooring of different housing systems influences the biomechanics of the claw and therefore incidence of lameness and, as a direct consequence, milk yield and reproduction. Bergsten and Frank (1996) found that flooring was the most important factor in developing laminitis in heifers and that rubber mats provided a clear improvement to concrete floors with regard to lameness, especially around parturition. Blowey (1998) reported an incidence of lameness of approximately 25% in British dairy cows and noted the close relationship between cow comfort and type of bedding used in the housing system. Cook (2003) reported a greater incidence of lameness in cows housed on hard floors; and a greater incidence of claw lesions was found accordingly (Cook et al., 2004).

Lischer and Ossent (2001) discussed biomechanical factors as they related to laminitis and an increased number of sole ulcers. They cited factors such as body weight, poor or no claw trimming, and conformational abnormalities of cows housed on hard floors. Hultgren and Bergsten (2001) showed the positive influence of rubber mats in tie-stall dairy production. Webster (2001) expressed the opinion that parturition sets in motion a chain of events that can cause severe foot lameness and concurrently large amounts of mechanical stress on the claw. Interaction between bovine claw horn architecture and material properties of the floor was shown by Voges et al. (2004). They found that keeping animals on softer floors improved horn quality by, among other things, increasing the number of tubules and quality of intertubular horn.

Laven and Livesey (2004) and Somers et al. (2003) showed that straw bedding reduced the development of sole hemorrhages compared with all other types of stall mattresses. Fregonesi and Leaver (2001) reported longer occurrences of lying and rumination when cows were kept on straw bedding, but no positive correlation was found with claw scores, locomotion scores, or the

Figure 3. Finite element model claw expressed in logarithmic scale of floor set 3 (model claw being loaded parallel to a 28-mm slot); circles and numbers indicate the 30 positions where stress values were measured (see Table 1).

incidence of lameness. Vokey et al. (2001) tested the effects of free stall surfaces, specifically concrete floors with sawdust, deep sand-bedded stalls, and rubber mattresses in 6 different combinations. Deep sand-bedded stalls were found to be best with regard to hock lesions and no evidence was found that mattresses conferred an advantage over concrete flooring. Those authors discouraged the use of rubber-coated alleys because cows tended to lie down in the alley walkways resulting in hygiene and mastitis problems.

Phillips and Morris (2000), measured, among other traits, walking behavior, stride length, and stepping rate of cows housed in deep- or medium-deep slurry of excreta compared with concrete floors, and found the effects of nonhygienic floors to be purely negative.

These well-accepted facts led to the question of stress within the claw capsule as a possible primary factor and biomechanical cause for lameness. Initial work using FEA compared hard and soft flooring and their effects on the bovine claw (Hinterhofer et al., 2005b). The same model claw was used in the latter study to compare the different flooring systems as in the present study. Specific points of high stress were found, logically, at the point of contact at the edge of slats and

the end of the short stand. The WBB of the dorsal and dorsal abaxial wall and of the bulbar region and the axial wall showed the greatest stresses. Pressure-plate investigations by van der Tol et al. (2002) also found weight distribution on a flat surface to peak in the bulbar region. In addition, the pedobarograms of Scott (1988) showed stress distributions in agreement with the present results. De Belie and Rombout (2003) monitored the foot-to-ground pressure distributions in an in vitro study with dissected toes, producing very comparable test conditions to a static FE calculation as performed for the present study. An I-scan pressure measurement system was used, showing outputs at a load of 1,000 N on concrete flooring with almost identical high stress values in the WBB of the dorsal abaxial wall and in the bulb. Equally, almost no stresses in the center of the sole and the bulb were found.

The FE claw model on the solid floor surface (floor set 1) calculated the greatest stress values in the region of the WBB of the abaxial claw wall of the toe and in the bulbar region. The WBB of the abaxial lateral wall and that of the axial exhibited rather small stresses, more evenly distributed, and without peaks. Within the horny capsule, aside from the WBB, greater stresses

occurred in the axial wall in one focal stress zone near the coronet and one close to the dorsal margin. The rest of the claw capsule was evenly strained with small stress results. Similar results were shown by the FE model claw loaded on a slat perpendicular to the axial and abaxial wall (floor set 5). The lack of support in this central part of the claw obviously presents a physical or mechanical deficiency to the claw. The reason therefore may be found in the natural claw form, which has little weight-bearing surface on the central, axial, concave area of the sole, and may even do without the central WBB of the abaxial wall, an area prone to horn defects and white line disease. This lack of weight-bearing surface can be compensated by other parts of the dorsal and axial wall and the bulb region. The model claw without support under both the WBB on the axial and the central abaxial side only calculated 133% of the stress compared with floor set 1.

Floor sets 2, 3, 4, 5, and 6 simulated situations in which the bovine model claw was not fully supported, but most of the main force-transmitting structures were in use, namely the WBB of the dorsal wall, the WBB of the dorsal abaxial wall, and the WBB of the heels. The predominant dorsal abaxial WBB, as seen in all pressure-plate studies, was the most important part of the wall with regard to loading. Moreover, the bulb of the claw, although soft and yielding, transmitted the load from the bony structures of the palmar and plantar part of the toe to the ground surface. Reducing the supporting area increased stress values in the loaded hoof segments, as all pressure was the result of force concentrated on a specific area as related by the equation $\text{Pressure} = \text{Force} \times \text{Area}$, as long as the basic structures remained the same. In floor set 7, the situation was simulated in which the bovine claw was forced to land on the axial structures, leaving the abaxial WBB unsupported. This model calculated the greatest stress peaks, due to a total change of the weight-bearing area and the unstable loading positions, with the claw straining for secure interdigital unity.

Peak stresses seen in all floor sets showed comparable values, with the exception of floor set 1, in which generally smaller stress values were seen in the claw. In floor set 7, however, exceptionally large stresses were detected in the WBB of the dorsal wall and the bulbar region. The model geometry used allowed comparison of the FEA results only to similarly shaped real hoof capsules. Even if the shape is identical, factors such as cleanliness, moisture content, individual claw wall and sole thickness, body weight, and surface properties of the flooring have to be dealt with separately. An exciting facet seen when interpreting the results in this study, which has consequences for other studies of non-technical components, was the fact that proximal axial

wall, although not actually loaded in the FE model claw, exhibited the greatest stress of the bovine hoof wall. From the point of view of mechanical stress, differences between stress values in the model claw on different slatted floors vs. stress values in the model claw only partially supported (floor set 2) were minimal.

The solid flooring showed the smallest peaks of stress due to its wide area of support. In fact, the simple mechanical relationship of body mass to weight-bearing surface seemed to be crucial. Different factors such as individual claw properties, trimming status, and standing time with the possibility of selective overloading, especially in a pathological claw form, may lead to greater stresses in the claw capsule than calculated in the presented floor sets. Further, the isotropic material situation still leaves some questions unresolved that may result in slightly varying displacements.

In a real-life situation, the simplicity of FEA results is tempered by the complexities of bovine housing. The possibility of traumatic injury, the economic realities of modern farming, cleanliness and its management, and grip and abrasion may overrule, in this case, the importance of the differences in the loading conditions seen in the claw capsule in our model, at least in this first overview. Finite element analysis in static loading is not enough to define proper guidelines for flooring systems, but stress distribution in the model claw capsule loaded on the floorings studied gives very good input for better interpretation of pressure plate and force plate results and for applying these results to management. As long as slatted floors are used in intensive dairy production, every possible effort should be made to optimize this use of a potentially hazardous element of bovine housing.

CONCLUSIONS

Comparison of 7 hard flooring systems in FEA showed minimal differences in mechanical stress in the claw on the various slatted floors, but a distinct difference between the solid surface floor and slatted floors was calculated. From the point of view of mechanical stress to the claw, full support of a solid floor, with no consideration of any other factors, would be a better choice over any kind of slatted floor. Stress distribution in the model claw on solid flooring was more even and maximum stress values (100%) were smaller than on slatted floors. Focal pressure peaks increased from 133 to 162% in the FE model claw loaded on slatted floors or with only partial support to the main weight bearing structures, and was far above 281% in the FE model claw when not supported under the abaxial wall. Other factors like cleanliness, grip, and economics complicate the clear case for solid flooring, but knowledge of the

mechanical stresses seen in cow claws on slatted flooring should be integrated into decisions made on floor design.

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